Identifying Periods of Financial Stress: The Role of High Frequency Financial Market Data*

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Abstract

We show that periods of financial stress (or crisis) can be distinguished using the characteristics of high frequency exchange rate trade data. Using eight exchange rates for Asia-Pacific economies plus India against the US dollar we show that their high frequency observations are consistent with a process containing both Brownian motion and discrete jumps. For four identifiable crises during the period 1996 to 2013 - the Asian, dot-com, US subprime and European crises - jump detection statistics are distinctly different than in non-crisis periods for each exchange rate. Consequently, we apply a new indicator for change in the jump behaviour of the currencies to determine a time line of high stress days as exceedances above a 4 standard deviation threshold. The results show the distinct differences which emerge from applying such measures to alternative exchange rate regimes; with floating regimes indicating more stressful days than managed regimes. We link the identified days to news events within a 3 day window, finding a great variety in the source of these stressors. The next step in our agenda is to determine the predictive ability of these indicators and the potential for combining them with traditional early warning systems.

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1 Introduction

Prompt detection of periods of financial stress may provide important time to marshall resources with which to avoid the onset of full-blown crisis conditions. Although a reliable early warning system would be of significant value, it is proving particularly difficult to obtain one with reliable forecasting properties; see for example Edison (2000) and more recently the work by Ghosh et al (2009). A viable alternative is to take advantage of the information available in the changing behavior of high frequency financial markets data about conditions of potential stress in those markets - an extension of market based proposals in the IMF(2010) Early Warning Exercise. Dealing with stresses before they become full blown crises may be both feasible and have positive outcomes.[1]

This paper takes advantage of recent developments in characterizing the behavior of high frequency financial market data to develop indicators of financial stress. Intra-daily frequency data is now in use measuring systemic risk in the banking sector (Dungey et al 2012, Brownlees and Engle 2012, Diebold and Yilmaz, 2011), daily data in detecting crises and bubbles in other markets (Wang and Nguyen Thi 2013, Addo et al 2013, Phillips and Yu 2011), and there remains a considerable number of developments in the lower frequency literature such as Phillips et al (2012) who provide a test for multiple bubbles in monthly data.

The conventional approach to detecting financial market stress and early warning systems largely relies on data available at the frequency of either real macroeconomic indicators or balance sheet data; for example the BIS proposal for detecting globally systemically important financial institutions will rely on annual balance sheet data updated every three years; Eichengreen et al (1996) use quarterly data on currencies, reserves and interest rates; Edison (2000) considers monthly data across the real and financial sectors. Claessens and Kose (2013) provide an overview of the dominant methods used for identifying different types of crisis - emphasizing the role of agencies or large identifiable events

[1] For example, Dungey and Gajurel (2013) show that avoiding particularly the idiosyncratic channels of contagion reduces the cost of banking crises.

such as defaults and rating agency downgrades for sovereign debt crises; information on mergers, runs and fiscal costs for banking crises, annual capital flows and output collapses for balance of payments crises and the much more easily obtained thresholds applied to the rate of currency depreciation for currency crises. Other reviews and discussions of crisis dating may be found in Bordo et al (2001), Jacobs et al (2005) and Laeven and Valencia (2008). Each of these methods uses at most monthly data observations. Dating crises through lower frequency data has the advantage that it is able to detect the presence of real economy effects, thus it is clear when crisis events have become economically costly. For example Laeven and Valencia (2012) calculate an average cost of 23 percent of GDP associated with banking crises from 1970-2011, while Bordo et al (2001) documented average losses of about 6 percent for both banking and currency crises individually, but over 18 percent for so-called twin crises for 1973-1997.

Using high frequency data for early detection of financial market stress is predicated on the idea that it is possible to calm market conditions before a full-blown crisis emerges - the premise underlying the suite of indicators proposed in the IMF-FSB Early Warning Exercise; see IMF (2010). Consequently an indicator such as we propose can not be easily assessed against whether it correctly predicts a crisis. The presence of revealed false signals (where the index suggests stress but no crisis emerges) is not an appropriate metric. Rather, this paper is concerned to show whether high frequency data can reveal periods of significant stress emerging in markets via changes in the behavior of the data generating process in a manner which allows both market participants and regulatory bodies to be aware of these changes in a timely manner.

Our application is to eight important currencies in the Asia-Pacific region plus India; Australia, Indonesia, Japan, Korean, Malaysia, Thailand and Singapore. We examine the exchange rates of these currencies against the common numeraire currency of the US for the period from January 1, 1996 to April 10, 2013, thus incorporating three known crisis periods of the 1997-98 Asian crisis, the 2001 dot-com crisis and the 2008-2009 global financial crisis. The domestic currency selection includes three developed markets of which the Japanese yen and Australian dollar are respectively the third and fifth most traded currencies in the world (BIS, 2010)[2], and five emerging financial markets in India, Indonesia, Korea, Thailand and Malaysia. These eight exchange rates represent different exchange rate regimes. The Japanese yen and Australian dollar have floated for the entire sample period; with their respective float dates in 1973 and 1983 respectively. While the Indian rupee floated in 1993, it is classified by the IMF as a managed floating with no pre-announced path for the exchange rate regime. This same classification applies to the Indonesian rupiah. The Thai baht was pegged to the US dollar prior to the Asian crisis, with the float of the baht on July 2, 1997 a date that is widely used to mark the start of that crisis. The Korean won also floated during the crisis in December 1997 as part of the conditionality of an IMF assistance package; prior to this period it had operated as a managed float. The Malaysian ringgit moved from a floating regime to a peg against the US dollar during the Asian crisis in September 1998 and returning to a managed float in July 2005. Singapore has operated a managed float during the whole sample. Alternatively, Patnaik et al (2011) classify India, Indonesia, Thailand as managed floats for the period since 1999, with Malaysia joining them in 2005 and Korea classified as a free float - they note that during the Asian crisis there was a considerable increase in exchange rate flexibility in the region, which has not been replicated during the Global Financial crisis in 2008-2009. As there are conflicting classifications of currency regime for many countries, we use as the main reference the IMF reports.

We present new results which first characterize the behavior of these exchange rates over the sample period, showing that each exchange rate can be characterized as containing both jumps and Brownian motion - consistent with most underlying theoretical specifications of continuous time finance. To our knowledge the only prior work in this area is by Erdemlioglu et al (2012) for the JPY/USD and EUR/USED exchange rate over the period January 1995 to

[2] The Singaporean dollar is 12th, the Malaysian ringgitt 25th and Indonesian rupiah 29th by turnover in the BIS survey, and the Indian rupee is not separately identified. However, only Singapore has more than 1 percent of the total turnover.

December 2009, and we confirm their results for the yen.

We show that the characteristics of the distribution of the jump detection statistics changes dramatically during pre-identified periods of financial stress and periods of calm. As a consequence we consider the potential for these indices to detect stressful periods in a timely manner.

Applying the stress detection statistics to the different currencies with a standard threshold we determine the dates for which the index suggests there is some stressful event. There is a large discrepancy between the numbers of days highlighted for different countries, ranging from only 4 days in Malaysia to over 100 in Australia. This detection rate is closely aligned with the currency regime in place. The lowest stress detection currencies are those which are associated with a managed float for most of the period; that is Malaysia and Singapore. The highest detection rates are associated with freely floating exchange rates - reflecting that in this case the exchange rate is the pressure outlet for events in the economies involved; it is the mechanism of adjustment.

In light of these results we propose alternative thresholds for exchange rates based on their operating regime, and document from newspaper and internet searches newsworthy events occurring within a 3 day window of the nominated date.

The paper proceeds as follows. Section 2 outlines the statistics which have been developed to characterize the data generating process of high frequency univariate data, and particularly introduces the index of stress to be used in this paper. The dataset of eight exchange rates is briefly outline in Section 3, and empirical results on the characteristics of this data are given in Section 4. Section 4 also contains evidence on the behavior of these statistics for our exchange rate data in pre-identified periods of calm and stress to demonstrate the empirical validity of our measures. We then report the results of applying the high frequency stress indicator to the exchange rates to identify specific days of stress endogenously and categorize the results with respect to exchange rate regime. Section 5 concludes with our plans for further assessment of the potential gains from the approach to identifying financial stress proposed in this paper.

2 Modelling Framework

Assume that the price for an individual asset denoted X_t, evolves as follows:

$$\begin{aligned} X_t &= X_0 + \int_0^t b_s ds + \int_0^t \sigma_s dW + \\ & \int_0^t \int_{[|x| \le \varepsilon]} x(\mu - v)(ds_x, dx) + \int_0^t \int_{[|x| > \varepsilon]} x\mu(ds_x, dx) \end{aligned} \quad (1)$$

which is a semimartingale of the form proposed by Ait-Sahalia and Jacod (2009,2010,2012). It comprises a non-zero mean, drift, Brownian motion and two potential jump components – one representing small (infinite) jumps and the other larger (finite) jumps, separated by a threshold, ε. Over a stream of papers, Ait-Sahalia and Jacod (2008,2009,2010,2012) propose a number of statistics to determine which of these potential processes are evident for an univariate high frequency series. As is usual, we work in the discrete version of this process, examining the behavior of $\Delta_i^n X$, which represents the intra-period return for the i^{th} period in the n intradaily observations.

A well-known statistic for high frequency data is the volatility proxy, realized volatility, given as the sum of squared intra-daily returns;

$$RV = B(2, \infty, \Delta_n) = \sum_{i=1}^{T/\Delta_n} |\Delta_i^n X|^2 . \quad (2)$$

However, this can be extended to higher powers, and for $p \geq 2$ we may write

$$B(p, \infty, \Delta_n) = \sum_{i=1}^{T/\Delta_n} |\Delta_i^n X|^p . \quad (3)$$

Further, we can also consider this statistic for a truncated section of the distribution – Ait-Sahalia and Jacod (2010) suggest truncating the tails, and introducing a truncation value u_n, such that when $|\Delta_i^n X| > u_n$ the observation is omitted from the statistic. We denote this as follows:

$$B(p, u_n, \Delta_n) = \sum_{i=1}^{T/\Delta_n} |\Delta_i^n X|^p \, 1_{\{|\Delta_i^n X| \le u_n\}} \tag{4}$$

It turns out that we have three tools with which to describe the behavior of high frequency financial series; the power of the function given by p, the truncation choice, u_n, and additionally sampling frequency. Denoting the baseline sampling frequency as $k = 1$, we can then denote other frequencies by means of, for example

$$B(p, u_n, k\Delta_n) = \sum_{i=1}^{T/\Delta_n} |k\Delta_i^n X|^p \, 1_{\{|k\Delta_i^n X| \le u_n\}}. \tag{5}$$

2.1 Statistics

We adopt two of the statistics to describe the behavior of high frequency data generating processes developed in Ait-Sahalia and Jacod (2009,2010) to detect the presence of jumps and Brownian motion respectively. To detect whether a series contains statistically detectable jumps (or discontinuities) consider the following;

$$S_J(p, \infty, k, \Delta_n) = \frac{B(p, \infty, k\Delta_n)_T}{B(p, \infty, \Delta_n)_T}.$$

The basis of the S_J statistic is that sampling the data at two different frequencies, $k = 1$ and $k > 1$ (usually k is an integer, although this is not strictly necessary), should reveal permanent discontinuities. This statistic is defined for $p \geq 2$, and is applied across the entire distribution of returns (that is $u_n = \infty$). Theoretically this statistic converges as follows (see Ait-Sahalia and Jacod, 2012):

$$S_J\left(p, \infty, k, \Delta_n\right)_t \xrightarrow{p} \begin{cases} k^{p/2-1} & \text{no jumps and no noise} \\ 1 & \text{jumps and no noise} \\ 1/k & \text{additive noise dominates} \\ 1/k^{1/2} & \text{rounding error dominates} \end{cases}$$

The second statistic detects the presence of Brownian motion as the continuous component of the series. In this case the data are assessed by sampling at two different frequencies, but with truncated distributions. That is, S_W is an inverted truncated analogy to S_J, assessed over $p < 2$ and $k \geq 2$.

$$S_W(p, u_n, k, \Delta_n) = \frac{B(p, u_n, \Delta_n)}{B(p, u_n, k\Delta_n)}$$

The theoretical distribution of this statistic is given in Ait-Sahalia and Jacod (2012) as follows:

$$S_W(p, u_n, k, \Delta_n)_t \xrightarrow{p} \begin{cases} k^{1-p/2} & \text{Brownian motion present and no noise} \\ 1 & \text{No Brownian motion and no noise} \\ 1/k & \text{additive noise dominates} \\ \text{no limit} & \text{rounding error dominates} \end{cases}$$

Finally, we make use of the statistic proposed in Dungey et al (2011), which takes advantage of the extreme returns – that is those which are captured in S_J but not in S_W.

$$S_{TI}(p, \widetilde{u_n}, k, \Delta_n) = \frac{B(p, \widetilde{u_n}, \Delta_n)}{B(p, \widetilde{u_n}, k\Delta_n)}$$

where we use the notation $\widetilde{u_n}$ to denote that we consider $\{|k\Delta_i^n X| > u_n\}$. More explicitly

$$B(p, \widetilde{u_n}, k\Delta_n) = \sum_{i=1}^{T/\Delta_n} |k\Delta_i^n X|^p \, 1_{\{|k\Delta_i^n X| > u_n\}}. \tag{6}$$

We can go further than this to examine the left and right tails separately, denoting S_{TI}^+ and S_{TI}^- respectively as

$$S_{TI}^+\left(p, \widetilde{u_n^+}, k, \Delta_n\right) = \frac{B(p, \widetilde{u_n^+}, \Delta_n)}{B(p, \widetilde{u_n^+}, k\Delta_n)}$$

$$S_{TI}^-\left(p, \widetilde{u_n^-}, k, \Delta_n\right) = \frac{B(p, \widetilde{u_n^-}, \Delta_n)}{B(p, \widetilde{u_n^-}, k\Delta_n)}$$

where $\widetilde{u_n^+}$ refers to $\{k\Delta_i^n X > u_n\}$ and $\widetilde{u_n^-}$ refers to $\{k\Delta_i^n X < -u_n\}$ where $u_n > 0$. At this point the theoretical distributions have not been formally proven, but as the statistic is simply the difference between the S_W and S_J in coverage, then by deduction we are clear that the following at least is true:

$$S_{TI}\left(p,\widetilde{u_n},k,\Delta_n\right)_t \xrightarrow{p} \begin{cases} k^{p/2-1} & \text{no extreme jumps and no noise} \\ 1 & \text{extreme jumps and no noise} \end{cases}$$

It is likely that the results for additive noise and rounding also follow through, however these do not concern the current paper.

2.1.1 Distribution of statistics

This section discusses the standardized version of statistics of S_J and S_W. The standardized version of $S_J(p,k,\Delta_n)$ is denoted as, $\widehat{S_J}(p,k,\Delta_n)$, where the statistic is developed in Ait-Sahalia and Jacod (2009) as:

$$\widehat{S_J}(p,k,\Delta_n) = \frac{S_J(p,k,\Delta_n) - k^{p/2-1}}{\sqrt{\widehat{V^c}}} \tilde{\ } N(0,1)$$

where $\widehat{V^c}$, the asymptotic variance of $S_J(p,k,\Delta_n)$, is based on the truncated power variation $A(\widehat{p,\Delta_n})$ and defined as follows:

$$\widehat{V^c} = \frac{\Delta M(p,k) A(\widehat{2p,\Delta_n})}{A(\widehat{p,\Delta_n})^2},$$

where

$$A(\widehat{p,\Delta_n}) := \frac{(1/M)^{1-p/2}}{m_p} \sum \ |r_i|^p \, 1_{\{|r_i| \le g(\Delta)^{\varpi}\}} \to \int \left|\sigma\left(s\right)\right|^2 ds,$$

$$M(p,k) = \frac{1}{m_p^2}\left(k^{p-2}\left(1+k\right)m_{2p} + k^{p-2}\left(k-1\right)m_p^2 - 2k^{p/2-1}m_{k,p}\right), \qquad (7)$$

$$m_p = E(|U|^p),$$

and

$$m_{k,p} = E(|U|^p \left|U + \sqrt{k-1}V\right|^p),$$

where U and V are two independent standard normal distributed variables.

The Brownian motion detection statistic $S_W(p, u_n, k, \Delta_n)$ has a standardized version,$\widehat{S}_W(p, u_n, k, \Delta_n)$,developed in Ait-Sahalia and Jacod (2010) as:

$$\widehat{S}_W(p, u_n, k, \Delta_n) = \frac{S_W(p, u_n, k, \Delta_n) - k^{1-p/2}}{\sqrt{\widehat{V^{BM}}}} \tilde{} N(0,1).$$

The asymptotic variance of $S_W(p, u_n, k, \Delta_n)$, denoted $\widehat{V^{BM}}$, is based on the ratio of two truncated power variation $B(2p, u_n, \Delta_n)$ and $B(p, u_n, \Delta_n)$ defined as follows:

$$\widehat{V^{BM}} = N(p, k) \; \frac{B(2p, u_n, \Delta_n)}{B(p, u_n, \Delta_n)^2},$$

where

$$N(p,k) = \frac{1}{m_{2p}} \left(k^{2-p} (1+k) m_{2p} + k^{2-p} (k-1) m_p^2 - 2k^{3-3p/2} m_{k,p} \right),$$

$$m_p = E(|Z|^p),$$

and

$$m_{k,p} = E(|Z|^p \left| Z + \sqrt{k-1} Z' \right|^p),$$

where Z and Z' are two independent standard normal distributed variables. The values of m_p and $m_{k,p}$ are computed as follows:

$$m_p = \frac{2^{p/2}}{\sqrt{\pi}} \Gamma\left(\frac{p+1}{2}\right),$$

$$m_{k,p} = \frac{2^p}{\sqrt{\pi}} (k-1)^{p/2} \Gamma\left(\frac{1+p}{2}\right)^2 F_{2,1}\left(\frac{-p}{2}; \frac{p+1}{2}; \frac{1}{2}; \frac{-1}{k-1}\right),$$

where Γ and $F_{2,1}$ are Gamma and Gauss's hypergeometric functions, respectively. As our statistic S_{TI} has the properties of being the difference between S_W and the inverted S_J we use the same form of $\widehat{V^{BM}}$ to obtain the standardized statistic.

2.2 The Stress Detecting Statistics

Dungey et al (2011) show that there is a distinct change in the extent of jump detection between non-crisis and crisis periods, but no change in the evidence for Brownian motion. That is, for a given currency, i, exchange rate against the numeraire US dollar, the jump detection statistic $S_{i,J}$, is expected to show change during periods of stress, while $S_{i,W}$ does not. Specifically, there is better detection of discontinuities during periods of financial stress. The detection statistics outlined here are designed to detect changes in jump behavior. This is not equivalent to saying that there is more jump activity during periods of stress; in many instances the proportion of jumps in volatility decompositions during crises falls relative to non-crisis periods which may be due to the reduction in the presence of noise, see Erdemlioglu et al (2012).

As $S_{i,J}$ changes under stress but $S_{i,W}$ does not, then as shown in Dungey et al (2011), we can use the behavior of the tail statistics $S_{i,TI}$ as a means of detecting changes in the data generating process for each individual financial series. The statistic $S_{i,TI}$ is by deduction a detection mechanism for the stressful periods. In this paper we implement rolling ratios of the value $S_{i,TI,t}/S_{i,TI,t-1}$ on a daily basis to pick up days of particular stress in each currency. We can hence consider the ratio:

$$S_{i,t} = \frac{S_{i,TI,t}}{S_{i,TI,t-1}}$$

where S_i picks up periods of stress associated with changes in the value of the domestic currency, although we do not at this point differentiate currency appreciations and depreciations. The upshot of this statistic is that when nothing changes between periods then $S_{i,t} = 1$.

As a threshold value for detecting stressful periods we adapt the approach common in the crisis detection literature of identifying a crisis when the $S_{i,t}$ index exceeds some confidence band beyond its mean; see for example Eichengreen et al (1996). That is creating a binary variable with the value of 1 for a period of stress as follows:

$$Stress_{i,t} = \begin{cases} 1 \text{ when } |S_{i,t}| > \frac{1}{T}\sum_{t=1}^{T} S_{i,t} + \theta\sigma_{S_i} \\ 0 \text{ otherwise} \end{cases}$$

where σ_{S_i} is the standard deviation of the ratio S_i for currency i. The choice of θ determines the coverage of the distribution, when $\theta = \{2, 3, 4\}$ imply $\{95.5\%, 99.7\%, 99.9\%\}$ confidence bands respectively. Eichengreen et al (1996) apply $\theta = 3$, but it is also common in high frequency data to consider $\theta = 4$ in testing for discrete jumps; see for example Dungey et al (2009), Lahaye et al (2011). We apply this standard threshold to all the data sets in our example, and as will become apparent we determine that $\theta = 2, 3$ may be appropriate for managed floats but that $\theta = 4$ is more appropriate for freely floating currencies.

3 Data

Data are sourced from the Thomson Reuter Tick History (TRTH) database, provided through SIRCA for the sample period January 1, 1996 to April 10, 2013. We retrieve the 5-minute returns for the following eight currencies against the US dollar: Australian dollar, Indian rupee, Indonesian rupiah, Japanese yen, Korean won, Malaysian ringgit, Singaporean dollar and Thai baht. Although the foreign exchange market is open 24 hours a day, 7 day a week, we exclude data from 00:00GMT Saturday to 24:00GMT Sunday. To avoid poor estimates of volatility, we also exclude days with too many missing values or low trading activity. Missing price observations are filled in with the previous price, and hence zero return. As holidays and missing data can vary with the domestic country the number of observations is slightly different for each exchange rate, but in general the complete sample results covers 4492 days and over 1.2 million observations for each currency. The exact numbers are given in Table 1.

4 Empirical Results

Table 1 presents the values of the mean test statistic for the tests for the presence of jumps, S_J and S_W. Histograms of the distribution of the daily results for the these statistics and their standardized analogues are provided in Figures 1 to 4. In our application we apply the values of $p = 4$ and $k = 2$ for S_J, and $p = 1$ and $k = 2$ for S_W and S_{TI}, following Ait-Sahalia and Jacod (2012) and Erdemlioglu et al (2012).[3] In the presence of jumps this statistic should converge to 1, but in the alternative case of no jumps (and no noise) to a value of 2, and with only additive noise to $1/k = 0.5$. Thus in the histograms, mass around 1 indicates support for the presence of jumps, mass to right centred around 2 is consistent with no jumps while mass to the left is consistent with the detection of noise.

The theoretical value of S_W in the presence of Brownian motion is $k^{1-p/2}$ which with $p = 1, k = 2$ corresponds to 1.4142. If additive noise dominates this will rather be $1/k = 0.5$, and in the absence of Brownian motion and noise the statistic will take the value 1.Table 1 clearly does not support either the absence of Brownian motion or pure additive noise. In the case of the histograms, mass around 1.4142 is consistent with Brownian motion, mass to the left centred on 1 is consistent with no Brownian motion.

It is clear from Table 1 that the mean values of S_J for each of the currencies varies between 1.18 (India) and 191.915 (Malaysia).[4] The formal tests presented in Table 2 show that the Australian, Japanese and Singaporean currencies do not reject the null of jumps in the data. However, the Indonesian and Malaysian currencies do at the 10% significance level, and the Indian at the 5% level. However, if we refer to the 0.1% significance level commonly adopted in high frequency financial econometrics, the critical value of 4 is not exceeded and there is evidence for the presence of jumps in all currencies. The mean values for the tests for the presence of Brownian motion range between 1.97 (Australia) and 12.06 (Malaysia), but in this case the formal tests shown in Table 2 do not reject the null of the presence of Brownian motion at any of the standard confidence levels. These statistics have previously been used to test for the presence of jumps and Brownian motion in the 30 components of the Dow Jones Industrial Average (Ait-Sahalia and Jacod, 2009, 2012; where the analysis is conducted on

[3] This implies that M(4,2)=160/3 in equation (7), see Ait-Sahalia and Jacod (2009).
[4] These statistics include outliers which we ommitted in Section 4.1.

the pooled results, not by individual assets), for Brownian motion in Microsoft and Intel stocks in Ait-Sahalia and Jacod (2010) and for the Japanese yen and Euro exchange rates against the US dollar in Erdemlioglu et al (2012), each of which supports these assets as having Brownian motion and evidence for jumps. Thus, our results are consistent with the existing evidence.

The S_{TI} statistics, as anticipated, all have values of around 1, consistent with evidence of jumps in the tails of the returns distributions. In each case, the standardized $\widehat{S_{TI}}$ accept the null of jumps, including for both positive and negative tails.

4.1 Periods of Stress versus Periods of Calm

In previous work, Dungey et al (2011) demonstrated that the S_J statistic showed a distinct change during periods of financial stress, using evidence from US Treasury notes traded on secondary markets. Specifically, they observed that the distribution of the S_J index showed a substantial increase in kurtosis during periods of stress - that is, the S_J statistic is much more certain about identifying jumps during crises than in non-crisis periods.

To confirm this phenomenon also exists in exchange rate data we compare the S_J statistics determined for each exchange rate during exogenously identified periods of financial stress, with periods of calm. We identified crisis periods starting from the daily realized variance (RV) computed from the 5 minute data across the sample for each of the 8 exchange rates. Periods of stress were determined as those in which the RV was higher than the median + 3 standard deviations, and periods of calm those with RV smaller than the sample median. Periods in which the RV is within the median and median + 3 standard deviations are considered as average volatility periods and are not considered. Since for each currency we will have several calm and stress periods, for this demonstration we selected only those with extreme RV values, and computed the statistics associated to S_J, after removing outliers with values of $S_J > 10$.

The results are shown in Table 3. It is apparent from the results that as in Dungey et al (2011) the kurtosis computed from the S_J statistics during periods of stress is higher than the kurtosis computed from data sampled during periods of calm. The change in skewness of the statistics is also consistent with the presence of crisis conditions in the underlying data, Fry et al (2010), although the properties with the S_J transformation of this data are not as notable in the US Treasuries market in Dungey et al (2011).

4.2 The Stress Indices

Having established that the jump characteristics do change during periods of crisis, we turn now to the construction of the $S_{i,t}$ indices of stress for individual currencies against the US dollar. Figure 5 shows these indices and Table 4 tabulates the number of exceedances above threshold for each currency by three different thresholds, $\theta = \{2, 3, 4\}$, corresponding to the $\{95\%, 99.7\%, 99.9\%\}$ confidence bands. It is immediately evident that the countries with freely floating exchange rate regimes across the whole sample - Australia and Japan - have the greatest numbers of observations above the threshold, while the countries with the most closely managed floats - Singapore and Malaysia - have the fewest. The remaining countries lie between these two groups.

A managed exchange rate will, by design, have a lower range of variation than a freely floating exchange rate, so that the freely floating rates will have greater numbers of discontinuities associated with the entry of information. This does not necessarily mean that these are more crisis-prone currencies. However, it does mean that threshold violations by managed float currencies should probably be taken seriously, and thus it is worth considering a lower threshold value for those currencies than for freely floating. The free float currencies will display changes in the jump behavior when they are exposed to more discontinuities. This could be due to information entering the markets - in accordance with the large literature which relates jumps to news for example; see Anderson et al (2007), Dungey et al (2009), Lahaye et al (2011). What we are particularly interested in is when there is a more substantial change in the behavior. Thus a higher threshold, such as the suggested 4 standard deviations is justified.

Table 5 provides the dates associated with exceedances of the 3 and 4 standard deviation thresholds for each currency in the sample. Using news services we have related particular events to the dates exceeding the 4 standard deviations for all currencies. The data were collected by consulting varied news sources for a 3 day window around the identified day. For brevity at this point we have not included the news events reports themselves.

4.3 Managed Exchange Rates:

Turning first to the cases of Malaysia, which includes both fixed and managed float regimes and Singapore which has a managed float throughout the sample. In Malaysia, exceedance of the 4 standard deviation threshold occurred on October 27, 2008 and December 31, 2010. Interestingly, the Asian crisis period did not bring up any of these cases unlike the conditions which prevailed later in the sample associated with the global financial crisis and events in Europe. Of these two dates the first seems related to the general crash in Asian stock markets on that day; with the Hong Kong market crashing by 12 percent and the Nikkei reaching a 20 year low. This followed the events in Europe over previous weeks which saw a significant number of countries appeal to the IMF for emergency aid, and was associated with a dramatic global loss of confidence. The second date is New Years Eve, and was declared a public holiday in Malaysia following the victory of the national football team in the ASEAN cup; thus trading was unusually thin and this day should more properly be deleted from our sample. The additional dates identified with a lower threshold were a mix of those associated with domestic Malaysian news releases and fears transmitted from crises in other regions; such as on the 27 January 2009 where the local stock market experienced significant turmoil in response to uncertainty in international financial markets.

In Singapore, 12 dates are identified as exceeding the 4 standard deviation threshold, and a further 8 exceed the 3 standard deviation threshold. Throughout 1997 and 1998 the events identified are clearly associated with the Asian financial crisis, and reflect the changing status of Singaporean assets to more aligned with regional problems during that period. From 1999 US economic conditions were responsible for most instances of pressure, and this feature prevailed until late 2010. From that period the US effects were punctuated by instances of Singaporean based news - particularly the varying expectations for Singaporean growth.

Korea and Thailand both experienced transitions from a fixed exchange rate regime to a more flexible regime during the 1997-1998 Asian crisis period, relatively early in our sample period. The Indonesian rupiah and Indian rupee have had managed exchange rate regimes with no pre-announced path. These four exchange rates have between 12 and 24 exceedances of the 4 standard deviations threshold during the sample.

India in 2001 has a run of stress indicators, consistent with the crash in Indian stock markets and financial problems associated with the dot-com falls in US based indices and highly leveraged positions premised on ever-rising stock prices. The consequent downgrade of Indian credit ratings in November 2001 is also represented in the stress index exceedances. News on poor economic conditions in both India and the global economy, as well as political tensions in the Indian-Pakistan border and the Gujarat riots in the first part of 2002 resulted in a cluster of exceedances in the first quarter of 2002. The implications of an international conflict, particularly around the second Gulf war led to stress in March 2003 and the freeing of imports of precious metals to India both led to observations greater than the threshold. Regulatory actions within the banking system in September 2006 and discussion over banking capital in early 2007 also sparked observations in our index. While there was an exceedance associated with a tightening in Indian monetary policy in April 2007, in early August of that year the effects of the developing credit crunch emanating from the US showed, with a large decline in the Indian stock market. A number of exceedances occurred in the following months. By 2010, however, the news associated with the exceedances pinpointed in our analysis has mixed sources; coming from measures to stimulate the US economy in February 2010 and from rallies in both major Indian stock markets (BSE and NSE) in early September 2011.

The Indonesian exceedances also largely correspond with Indonesian events in the first part of the sample. The first exceedance, in January 1996 expressed concerns about the high inflation rate and current account deficit in the economy, followed in April by large growth results. On June 12, 1996 an exceedance corresponds to the announcement that the central bank had widened the band in which the rupiah fluctuates without causing intervention. After the onset of the crisis, news was dominated by the poor economic outlook, including in December 1998 news that the economy shrank by over 13 percent that year with inflation of over 75 percent. In 2000 an improved economic assessment by the World Bank and further plans to cut the budget deficit also produced an exceedance. But by April that year falls in the equity market caused pressure in the currency markets. Agreement of terms of IMF plans in May 2000 and the new Indonesian Government in August 2001 also influenced the currency. Indonesian economic conditions continued to be the primary source of exceedances; including the announcement of the removal of petrol subsidies on January 24, 2002, a 50% drop in GDP growth announced in February 2002 and improved outlook for the Indonesian banking system in March 2003. The exogenous event of the tsunami which hit Indonesia on December 26, 2004 was felt in the currency markets in the coming week. By comparison the Indonesian rupiah has experienced relatively little stress associated with the global financial crisis, showing only one exceedance on 20 November 2008, which is more closely associated with data on Indonesian economic growth that global financial conditions.

The Thai timeline for exceedances shows some similarity to that of Indonesia. We begin in 1996 with exceedances in April and September associated with an expected continuation of high trade deficits and the announcement of the resignation of the then-Prime Minister Banharm Silpa-archa. He has been credited with laying the foundations for the 1997 Thai crisis, and the stress index begins to show associated exceedances in the coming period. On February 21, 1997, when the Thai central bank ruled out a program of currency devaluation the baht rallied, but following the float of the currency on July 2, 1997 and subsequent depreciation, the currency came under further stress with a cut in credit rating by Moody's in October 1997. By mid-1998, however, the pressures on the Thai exchange rate are mixed in their association with poorer US economic conditions in July 1998, and a more hopeful outlook for the Thai economy in the second half of 1998, despite junk bond ratings for three Thai banks by Standard and Poors. As with the Korean and Indonesian results, news on IMF programs can also cause the stress index to exceed the threshold; in December 1998 this was associated with the approval of IMF funds to Thailand after protracted negotiations. Plans to mitigate future crises via the establishment of mutual lending agreements between Asian countries, such as between Thailand and Japan in April 2001 also affected the exchange rate. In April 2004, the next exceedance concurs with speculation that the ASEAN Finance Ministers may agree that their economies were robust to a weaker US dollar. In 2008 there was some evidence of pressure on the Thai baht exchange rate in May associated with a poor economic outlook for the global economy issued by the IMF and in July 2008, associated with growing volatility in US stock markets and credit crunch conditions in Europe.

The Korean dates correspond quite closely to Korean specific events in first part of the sample; exceedances in April 1996 were associated with the Trade Minister of the time commenting that despite the appreciating won the country would not restrict capital inflows, and later in that year concerns over the domestic economy, particularly the current account deficit appeared. Despite the crisis, in December 1998 a spike appears related to a wider current account surplus, in November 1999 associated with strong growth expectations and in May 2000 by anticipated IMF projections for future growth associated with reviews of their programs. However, the remainder of that year and into 2001 was punctuated by stresses associated with drops in the KOPSI, which was sufficient to prompt support packages from the South Korean Government. The KOPSI underwent its largest one-day drop on September 12, 2001 following the 9/11 attacks. Although this does not show up in the currency stress index, the recovery approximately one month later did. By 2007 the events affecting exceedances in the currency were mixed, including on 14 December 2007 both the announcement of the Korean presidential election date and comments from Alan Greenspan on the increasing probability of a recession in the US. Much of Asia was affected by rising oil prices in this period, and on 27 May 2008 an index exceedance corresponds to the announcement of Asian central bank interventions to support depreciating local currencies. This was followed on October 24, 2008 by the announcement of a package of measures to support the economy through the global financial crisis, including a large interest rate cut and fiscal stimulus via tax cuts.

4.4 Free Floating Exchange Rates:

Amongst exchange rates which were freely floating across the whole sample considered here Australia experienced the fewest exceedances of the 4 standard deviation threshold (13), whereas Japan had 24. These exceedances are generally not common across the exchange rates, although there are some associated clusters. For example, stresses in late 1996 were evident in Japan prior to the traditional dating of the Asian financial crisis, and in mid October 1998, when Japan announced its bailout of the troubled banking system both Australia and Japan experienced a threshold event.

The exceedances evident for the Japanese yen are largely associated with news for the beleaguered Japanese economy, with evidence of slight brightenings and dimmings for the future of the economy. Of particular interest are the rumors of intervention against the falling yen in November 1997 and March 2000, as well as the banking crisis events previously mentioned. Pressure due to the global financial crisis is perhaps more evident in the yen than other Asian currency exchange rates, consistent with the US dollar and yen's role as the first and third most traded world currency. Exceedances were recorded on November 2, 2008 after the G7 Finance Ministers met in Japan, concerns over the length of the potential recovery from the crisis expressed in July 2008 and October 2008, and the announcement of an emergency funding program on December 5, 2008 to avert a credit crunch crisis. The election of a new

Government in Japan, overcoming the ruling coalition and appointment of a new Prime Minister caused some stress in September 2009. Unlike the tsunami affecting Indonesia, the response to the earthquake off the coast of Japan and subsequent tsunami on March 11, 2011 did not cause the stress index for the exchange rate to exceed its threshold, the exceedances for 2011 are associated with news first on a worsening outlook for Japanese debt issued by Moody's in February 2011 and then on downgraded economic projections released following the US FOMC June 22 meeting.

The Australian dollar exchange rate against the US dollar typically represent international or regional events. The stresses in early 1997 and in October 1998 particularly concern the pressures leading to the Asian crisis and the reaction to the LTCM near-collapse. The cluster of exceedances in 2001 conforms to stress surrounding the dot-com crisis, while October 29, 2004 represents the date on which the European Constitution failed to be implemented due to rejection by Dutch and French voters. The exceedance on 30 May 2006 seems partly to relate to (unfulfilled) expectations of a change in Australian monetary policy in the coming week, and a reaction to the earthquake in Java in the previous days. A (fulfilled) expectation of interest rate change at the November 2006 meeting is also associated with an exceedance in late October, and on November 24, 2006 the Australian dollar reached a then high against the British pound. Australia's relative lack of exposure to the global financial crisis is evidenced by the relatively few exceedances of the 4 standard deviation threshold in 2007-2009. One occurred on November 12, 2007 in the leadup to the Federal election and as the Australian dollar fell back from its high against the US dollar. The next disruption on July 16, 2009 is more difficult to align, as it corresponds with a speech by US President Obama on health care but no other obvious news events. However, the final date, May 23, 2013, represented a rally in the US dollar, so that the Australian dollar fell below parity to a one year low, in response to expectations that the quantitative easing program in the US would soon be finalized.

The range of different news items identified with the exceedances of the crisis indices point to the complexity of the origins of financial stress – ranging from political turmoil, through national disasters to banking failures and regulatory decisions to economic indicators. This is particularly the case when dealing with exchange rates which reflect not only global economic conditions, but also the direct influences of two different economies. In the cases examined here, the Asian exchange rates with mixed exchange rate regimes, which are also important emerging financial markets, demonstrated a strong proportion of exceedances associated with local news. For the more highly traded currencies of the Japanese yen and the Australian dollar, international events played a strong role; although domestic economic outcomes and the national disasters were clearly evident. The Indian results also present a mixed set of influences, but with a definite focus on shocks from elsewhere in the Indian financial system propagated through the stock market and banking sector. The managed exchange rate regimes of Singapore and Malaysia had the smallest number of exceedances, with the focus switching throughout the sample from domestic to international sources as predominant.

The results are not definitive in categorizing types of shocks associated with the crisis indicator exceeding the threshold values by either currency regime or country. They clearly demonstrate the complexity of the influence of events and economic conditions on exchange rates, and the rationale for wishing to have a suite of possible responses to stress in currency markets with which to potentially stop the emergence of a full-blown crisis. Clearly the policy response to an exceedance caused by the 'good' news of improved economic growth prospects is completely different to one caused by the 'bad' news of a credit rating downgrade or concerns over capital adequacy in the banking sector. This preliminary investigation into whether and how high frequency exchange rate data may be useful as an early indicator of financial stress shows how it is possible to align some threshold exceedance statistics with reported news events. However, future work will aim to build more complete models of how this may relate to the probability of full-blown crises, and most importantly, whether this information can help to build more robust early warning systems for detecting the onset of the conditions under which a financial crisis may be rapidly propagated and aid in designing prevention programs.

5 Conclusion

The contribution of this paper is an initial exploration of the use of high frequency exchange rate data to detect stressful financial conditions in eight Asia-Pacific countries including India, Australia, Indonesia, Japan, Korea, Malaysia, Singapore and Thailand. We provide the first characterization of the distribution of the high-frequency characteristics of the exchange rates for eight currencies against the US dollar and confirm the results on the Japanese yen US dollar exchange rate recently provided in Erdemlioglu et al (2012), with evidence for both Brownian motion and discrete jumps in each of the exchange rates considered.

The evidence of change in jump detection during periods of stress leads us to adapt the proposals of Dungey et al (2011) to provide a rolling index of stress detection in each exchange rate. Using a threshold for stressful conditions equivalent to 4 standard deviations of the index we identify days which exceed this threshold during the sample. The results immediately emphasize the role of exchange rate regime; managed exchange rate regimes have the fewest exceedances, and free floats the most. This result is entirely consistent with the use of the exchange rate to buffer against changes in expectations around a country's future performance. The chronology of days we identify are not inconsistent with identified news events.

This research has identified that high frequency financial data has the potential to provide useful, timely information about stress conditions in currency markets. By combining this information with the more widely used macroeconomic and lower frequency indicators of financial market stress, there is significant potential that this approach may contribute to providing better warning of the advance of crises. The rewards for avoiding or better managing financial crises are immense, and even small improvements in our ability to recognize and detect financial stress has the potential for enormous payoffs for the world economy. Future work will consider the predictive performance of these indicators and mechanisms for combining the high frequency information with more traditional approaches.

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Table 1: Test statistics for high frequency data on exchange rates against the US dollar: 1996-2013

Statistic	Australia	India	Indonesia	Japan	Korea	Malaysia	Singapore	Thailand
S_J	1.4898	1.1791	1.3409	1.7479	1.3426	191.9152	1.3641	1.0742
S_W	1.9656	2.0168	8.0891	2.0018	2.6402	12.0578	4.6067	7.5158
S_{TI}	0.9775	0.8979	0.8309	0.9995	0.8701	0.8610	0.7946	0.7657
S_{TI}^{+}	0.9767	0.8967	0.8310	1.0002	0.8883	0.8523	0.7971	0.7676
S_{TI}^{-}	0.9970	0.9019	0.8323	1.0181	0.9029	0.8422	0.8018	0.7665
$\overline{RV}x10^{-5}$	7.4864	1.5844	96.682	5.4960	18.727	4.5299	2.4284	47.00
N	1294272	1294272	1293984	1294272	1293408	1293696	1294272	1294272

Table 2: Standardized test statistics for high frequency data and associated variances

Statistic		Australia	India	Indonesia	Japan	Korea	Malaysia	Singapore	Thailand
$\widehat{S_J}$		-0.6910	-0.5912	-0.5948	-0.4628	-0.3988	2.6772	-1.0990	-1.1167
	σ	0.8634	2.3948	1.7867	0.8964	2.5368	1.7178	0.8273	1.0272
$\widehat{S_W}$	μ	5.6922	3.2322	9.1316	6.1706	4.1946	14.5172	8.8389	8.0368
	σ	0.0115	0.0513	0.1887	0.0108	0.0685	0.0756	0.0159	0.0586
$\widehat{S_{TI}}$	μ	-2.0316	-1.8473	-2.2976	-1.8986	-1.8972	-2.2107	-3.0079	-3.0686
	σ	0.0529	0.0949	0.0904	0.0551	0.1321	0.1465	0.0518	0.0569
$\widehat{S_{TI}^{+}}$	μ	-1.4533	-1.3142	-1.6113	-1.3624	-1.3154	-1.5561	-2.1339	-2.1426
	σ	0.1067	0.1884	0.1839	0.1100	0.2554	0.2789	0.1050	0.1184
$\widehat{S_{TI}^{-}}$	μ	-1.3940	-1.3032	-1.6488	-1.2959	-1.3136	-1.5998	-2.1106	-2.2089
	σ	0.1071	0.1884	0.1780	0.1112	0.2448	0.2729	0.1018	0.1097

Table 3: Statistics for exogenously identified crisis and calm

	Australia	India	Indonesia	Japan	Korea	Malaysia	Singapore	Thailand
Periods of stress								
Start	5-Sep-08	29-Mar-07	12-Dec-97	31-Dec-96	29-Oct-97	28-Aug-97	8-Aug-97	19-Jan-07
End	8-Jul-09	28-May-09	21-Oct-99	30-Jun-00	15-Sep-98	10-Sep-98	16-Apr-99	11-Mar-08
S_J								
Mean	1.8075	1.2049	1.0226	1.5826	1.2969	1.2012	1.0942	1.2098
Median	1.6024	1.0100	0.9078	1.3144	0.9999	0.9770	0.9860	1.0000
Skew	1.6947	4.8120	1.7845	2.5523	2.7376	2.8641	2.4566	1.5959
Kurtosis	4.3305	31.8771	5.2858	10.2231	9.6093	12.0924	12.2678	2.9037
Periods of calm								
Start	15-Apr-02	17-Dec-96	20-Sep-96	1-Oct-01	1-Jul-03	2-Jan-96	2-Sep-02	20-Feb-04
End	14-Feb-03	21-Nov-97	10-Jul-97	13-Dec-05	30-Jun-04	27-Aug-97	10-Mar-04	15-Apr-05
S_J								
Mean	1.3941	1.0920	1.2258	1.5994	1.2463	1.2979	1.2395	1.0300
Median	1.2259	1.0000	1.0084	1.3657	1.0165	1.0564	1.0521	0.9716
Skew	1.3424	2.4371	1.6309	1.9313	1.5744	1.9481	1.6072	1.2309
Kurtosis	2.4509	9.8043	3.1687	5.4838	3.4413	6.1985	3.8330	2.2182

Table 4: Number of days above threshold value for stress index for January 1996 to March 2013

Days	Australia	India	Indonesia	Japan	Korea	Malaysia	Singapore	Thailand
Days above 2σ	185	119	60	197	80	10	53	83
Proportion (%)	4.12	2.65	1.34	4,38	1.78	0.22	1.18	1.85
Days above 3σ	46	51	29	60	37	5	20	32
Proportion (%)	1.02	1.14	0.65	1.34	0.82	0.11	0.45	0.71
Proportion above 4σ	13	24	15	26	20	2	12	18
Proportion (%)	0.29	0.53	0.33	0.58	0.45	0.04	0.27	0.40
Days in sample	4492	4492	4493	4492	4491	4492	4492	4492

Table 5: Spikes where STI(t)/STI(t-1) is higher than the Median + 3STDV**

AUD	IDR	INR	JPY	KRW	MYR	SGD	THB
22-Jan-96	8-Jan-96 **	15-Feb-96 **	24-Jan-96	4-Jan-96	22-Dec-05	28-May-96 **	9-Feb-96
2-May-96	16-Apr-96 **	22-Apr-97 **	12-Apr-96	22-Apr-96 **	27-Oct-08 **	21-Jan-97	29-Apr-96 **
11-Jun-96	12-Jun-96 **	10-Jun-97	2-May-96	20-May-96	27-Jan-09	6-May-97 **	24-Jul-96
2-Dec-96	18-Oct-96	25-Nov-97	11-Jun-96 **	20-Sep-96 **	31-Dec-10 **	25-Dec-97 **	23-Sep-96 **
10-Apr-97 **	29-May-98	21-Aug-98	28-Jun-96	29-Dec-98 **	2-May-11	19-Mar-98	21-Feb-97 **
26-Mar-98	22-Jul-98	10-Jun-99 **	4-Sep-96	17-Nov-99 **		14-May-98 **	28-Oct-97 **
15-Oct-98 **	30-Dec-98 **	21-Jun-99 **	10-Sep-96	30-May-00 **		17-Nov-98	15-Dec-97
25-Jun-99	13-May-99	9-May-00 **	31-Oct-96 **	18-Oct-00 **		25-Nov-98	18-Jun-98
29-Jul-99	8-Dec-99 **	1-Aug-00	14-Nov-96 **	3-Apr-01 **		5-Feb-99 **	2-Jul-98 **
16-Sep-99 **	23-Feb-00 **	19-Oct-00	3-Dec-96 **	16-Jul-01 **		11-Feb-99 **	22-Jul-98 **
1-Nov-99	17-Mar-00 **	31-Oct-00	21-Jan-97	5-Oct-01 **		1-Jan-01 **	7-Aug-98
29-Jan-01 **	3-May-00 **	3-Jan-01	3-Jul-97	16-Oct-01 **		16-Mar-01	21-Sep-98 **
16-Apr-01 **	13-Sep-00	19-Feb-01 **	17-Nov-97 **	8-Jan-02		4-Sep-01 **	7-Oct-98 **
8-Aug-01 **	27-Nov-00	22-Feb-01	30-Jun-98	1-Feb-02 **		23-Feb-04 **	17-Dec-98 **
28-Sep-01	7-Mar-01	5-Apr-01 **	14-Oct-98 **	15-Oct-04		27-Jun-05 **	9-Mar-99 **
11-Nov-02	23-May-01	9-Apr-01	28-Dec-98 **	30-Jan-06		22-Dec-09 **	14-Mar-00
28-Jan-03	8-Aug-01 **	27-Apr-01 **	3-Jan-00 **	4-Jul-06 **		1-Jan-10	13-Apr-01 **
10-Dec-03	24-Jan-02 **	25-May-01 **	16-Jun-00 **	31-Oct-06		15-Jan-10	20-Dec-01 **
14-Jul-04	22-Feb-02 **	11-Jun-01 **	15-Dec-00 **	18-Jan-07		13-Apr-10 **	7-Oct-04 **
5-Oct-04	18-Sep-02	26-Jul-01	28-Feb-01	23-Nov-07		14-Sep-10	7-Dec-05
18-Oct-04	2-Dec-02	10-Sep-01 **	4-Jun-01	14-Dec-07 **			15-Dec-06 **
29-Nov-04 **	13-Mar-03 **	12-Sep-01 **	11-Oct-01	8-Feb-08 **			6-Jul-07
7-Dec-04	3-Jan-05 **	16-Oct-01 **	4-Dec-01	31-Mar-08			7-Jan-08
12-Aug-05	23-Nov-05 **	26-Nov-01	19-Aug-02 **	27-May-08 **			14-May-08 **
17-May-06	2-Jan-08	30-Nov-01 **	14-Nov-02	8-Oct-08			1-Jul-08 **
30-May-06 **	20-Nov-08 **	25-Dec-01 **	20-Jan-03	24-Oct-08 **			18-Sep-08
13-Jul-06	6-Oct-09	28-Dec-01 **	31-Oct-03	1-May-09			11-Feb-09
25-Aug-06	25-May-12	15-Jan-02	10-Dec-03 **	5-May-09			30-Jul-10 **
27-Oct-06 **	30-Aug-12	21-Jan-02 **	31-Dec-03	15-Feb-10 **			8-Sep-10
24-Nov-06 **		22-Feb-02	19-Jan-04 **	5-May-10 **			20-Sep-10 **
29-Dec-06		5-Mar-02 **	13-Feb-04	21-May-10 **			22-Mar-11
2-Aug-07		1-Apr-02 **	18-Feb-04	2-Jun-10			28-Aug-12
6-Nov-07		15-Aug-02 **	22-Mar-04	4-Oct-10			
12-Nov-07 **		13-Sep-02	25-Mar-04	3-Oct-11			
28-Nov-07		29-Oct-02	22-Apr-04 **	3-Oct-12			
30-Jan-08		14-Jan-03	6-Sep-04 **	25-Dec-12 **			
25-Apr-08		30-May-03 **	21-Sep-04	1-Mar-13			
17-Dec-08		4-Jul-03	20-Jan-05				
13-Apr-09		14-Jul-03	29-May-07				
16-Jul-09 **		29-Dec-03	12-Nov-07 **				
12-Apr-11		14-Jan-04	11-Feb-08 **				
31-May-11		16-Aug-04	11-Apr-08				
28-Sep-11		16-Aug-05	13-May-08 **				
23-May-12 **		23-Apr-07	7-Jul-08 **				
22-Aug-12		2-Aug-07 **	7-Oct-08 **				
21-Feb-13		16-Aug-07 **	5-Dec-08 **				
		21-Mar-08 **	7-Sep-09 **				
		15-Sep-08	1-Jan-10 **				
		26-Dec-08	16-Feb-10				
		3-Sep-12	22-Apr-10				
		4-Feb-13	23-Nov-10 **				
			22-Feb-11 **				
			1-Mar-11				
			23-Jun-11 **				
			31-Oct-11				
			30-Jul-12				
			14-Nov-12				
			28-Feb-13				
			26-Mar-13				
			1-Apr-13				

** higher than the Median + 4STDV

Figure 1: Non-standardized SJ

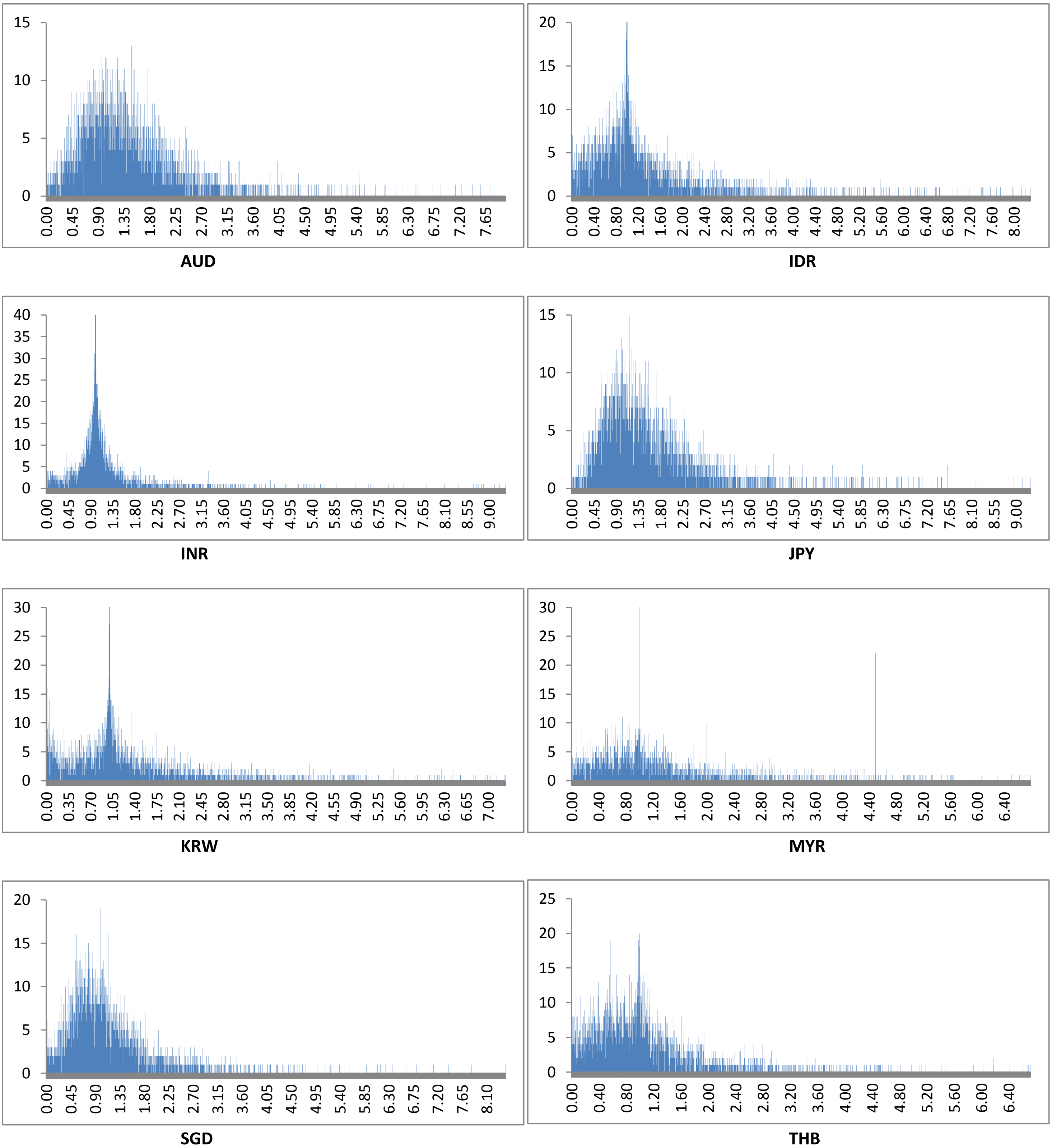


Figure 2: Standardized SJ

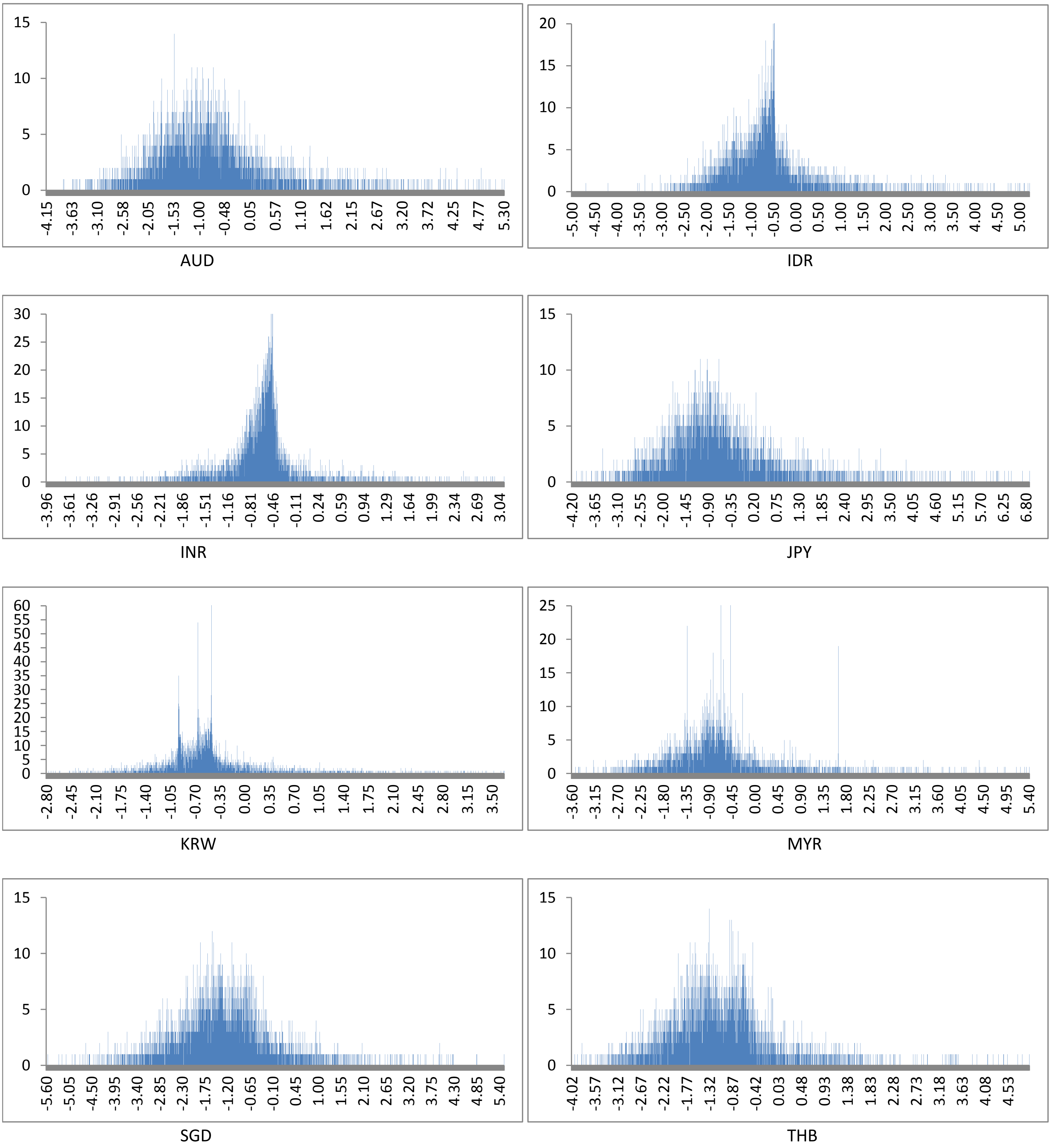


Figure 3: Non-standardized SW

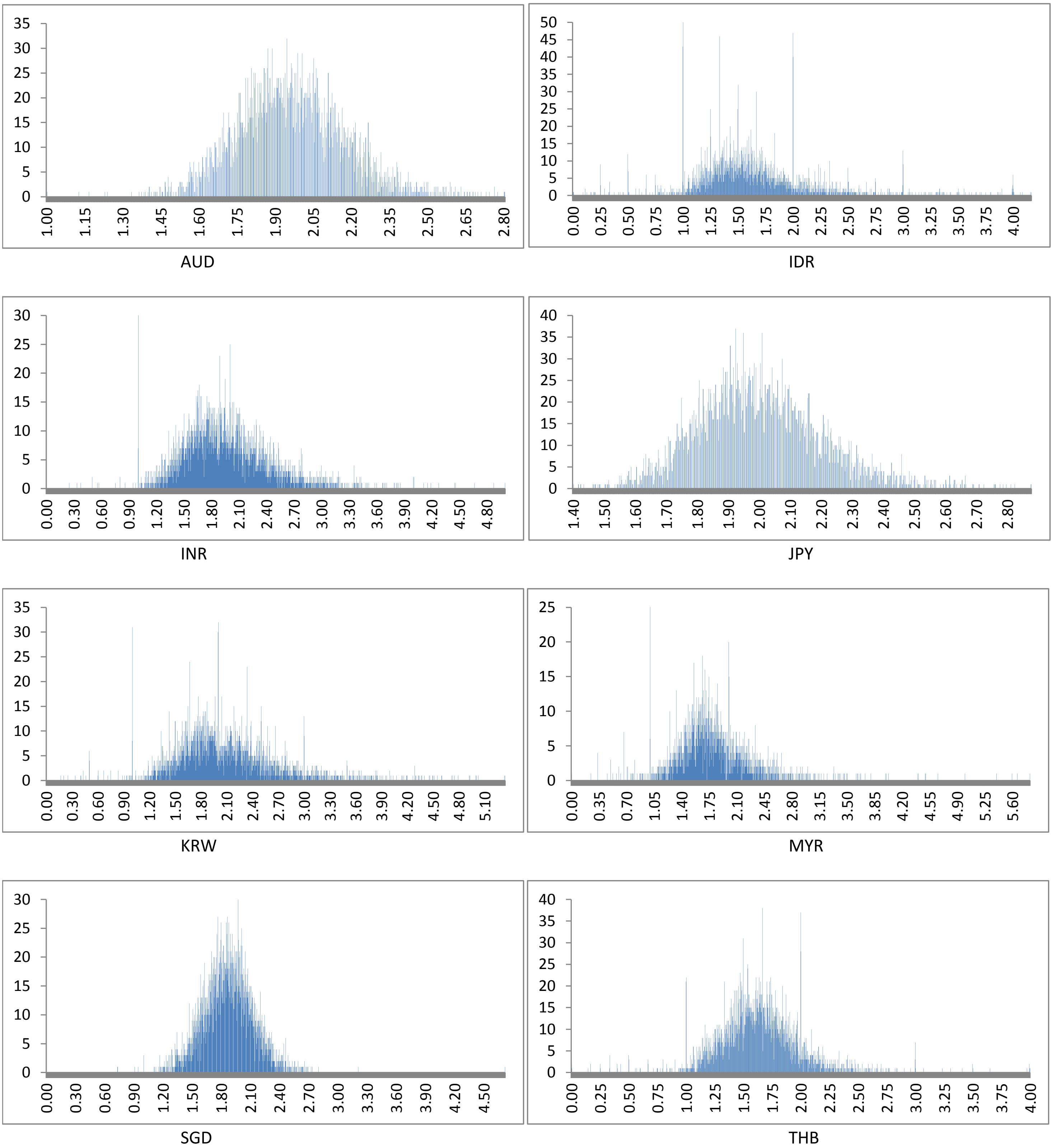
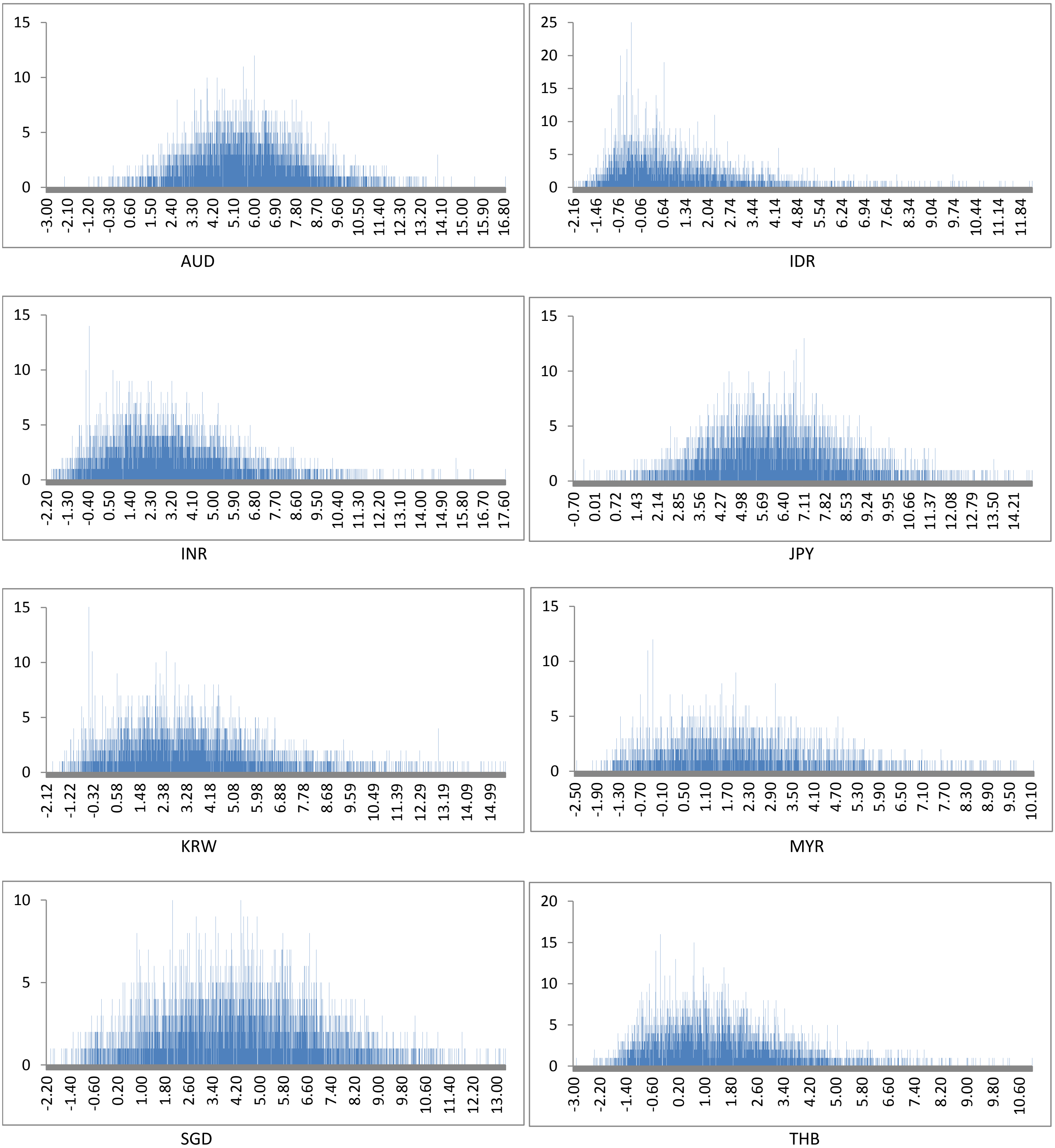
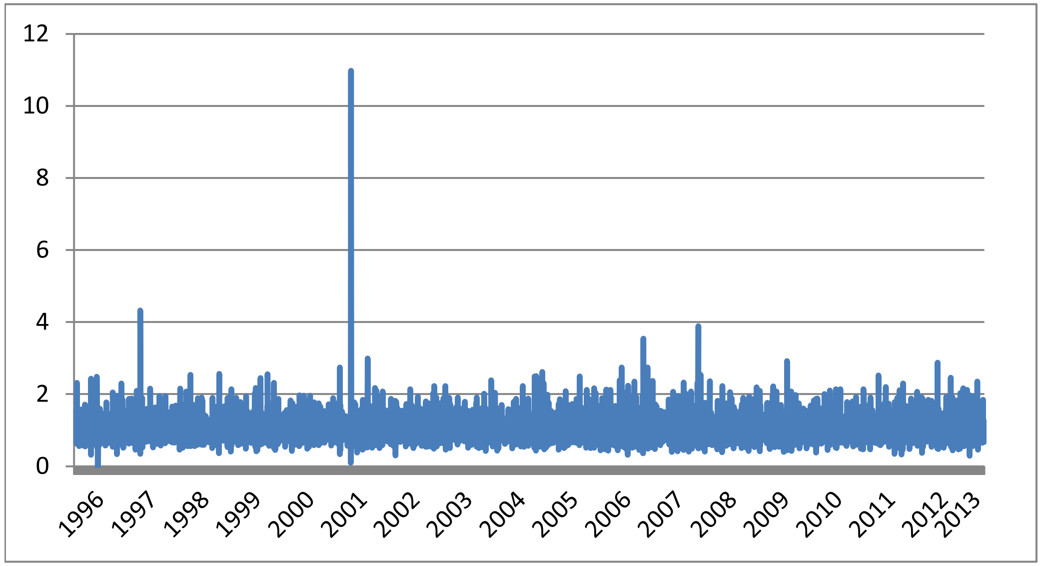


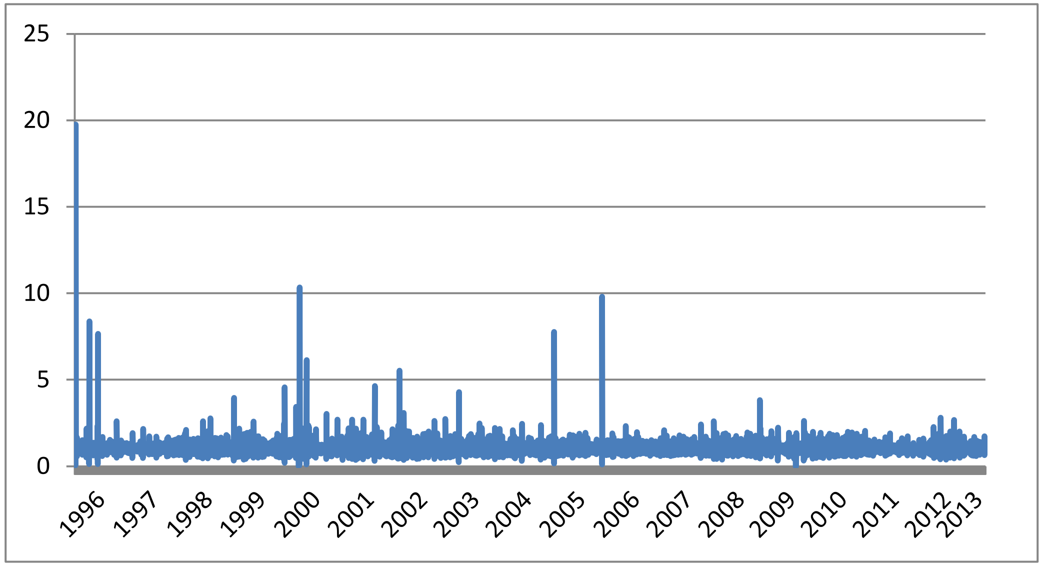
Figure 4: Standardized SW



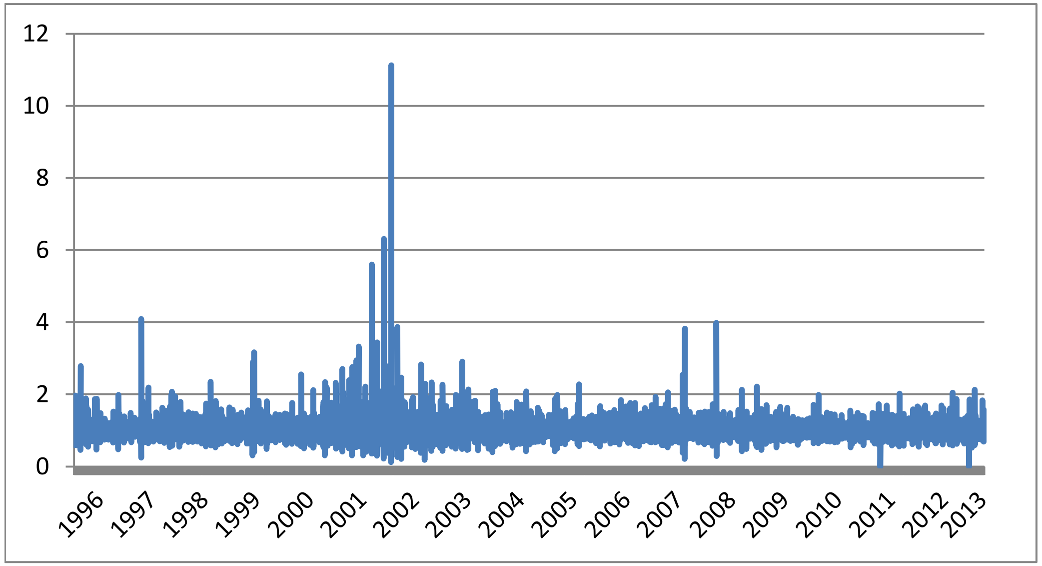
Graphs STI(t)/STI(t-1)



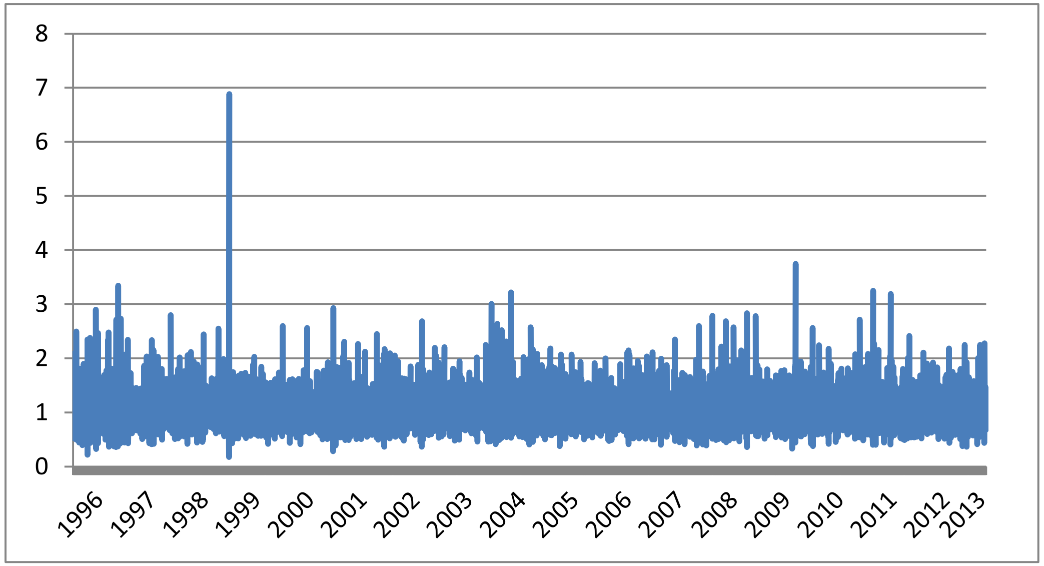
AUD



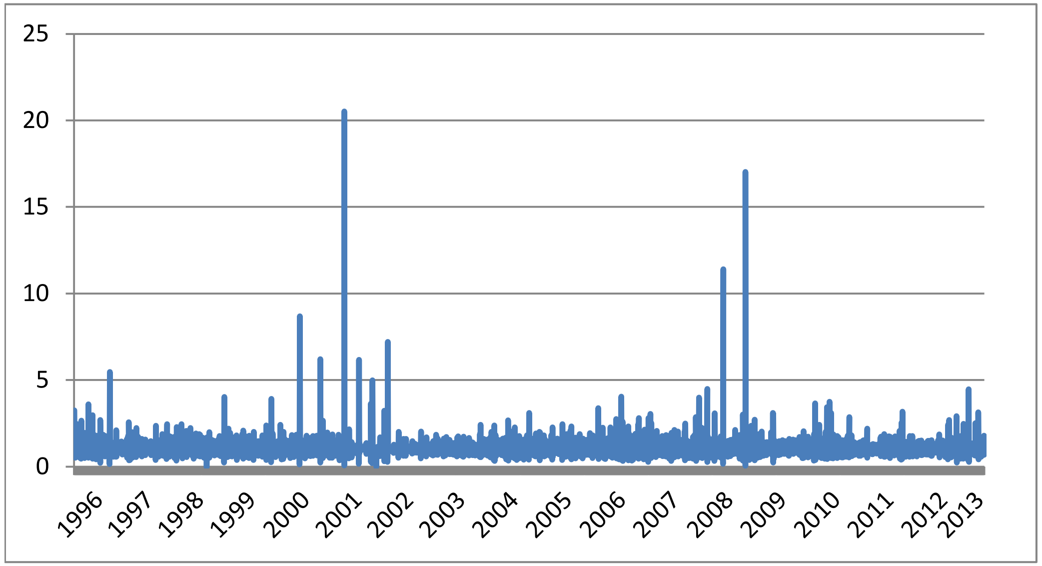
IDR



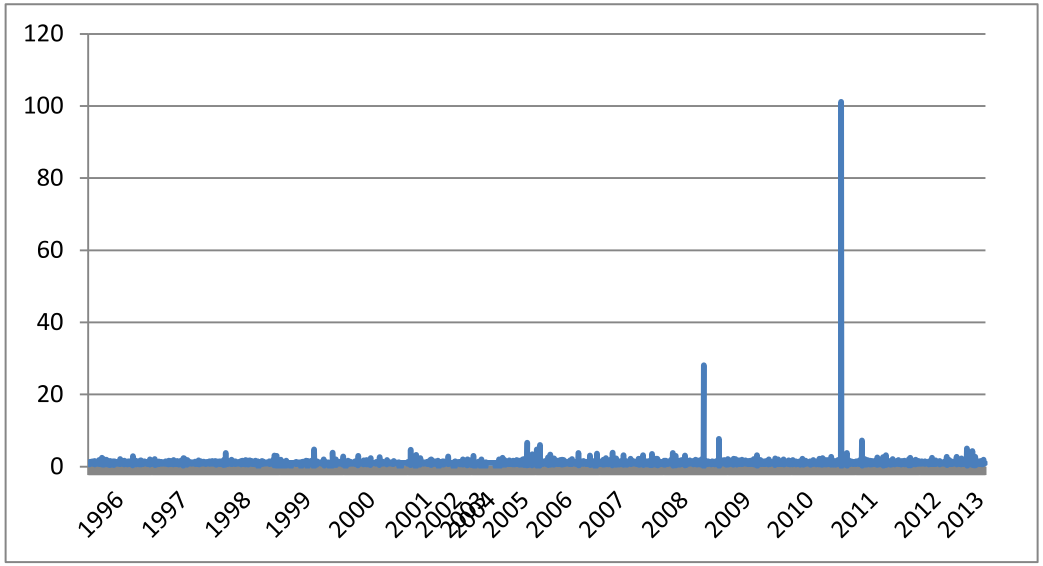
INR



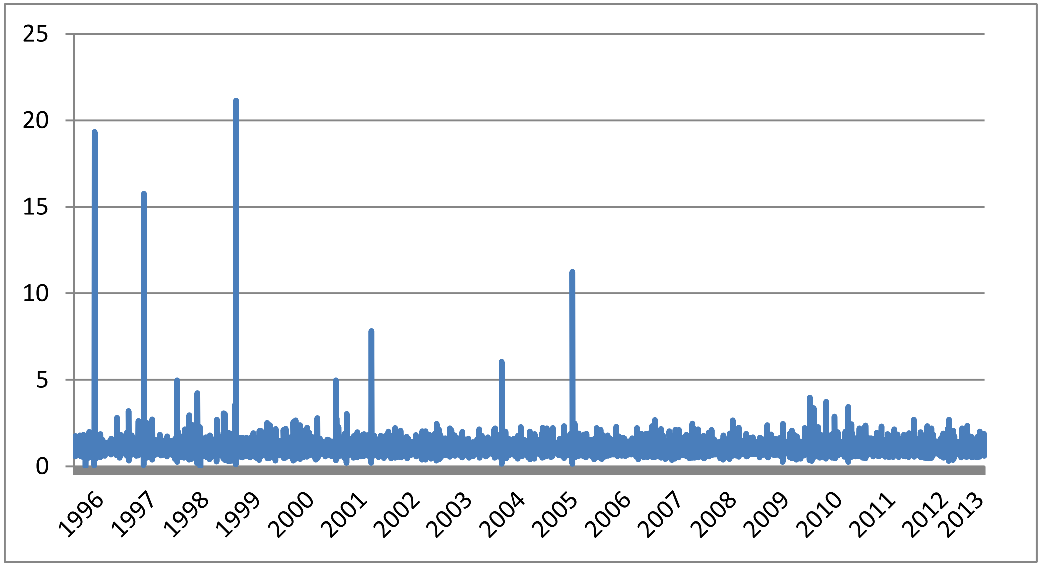
JPY



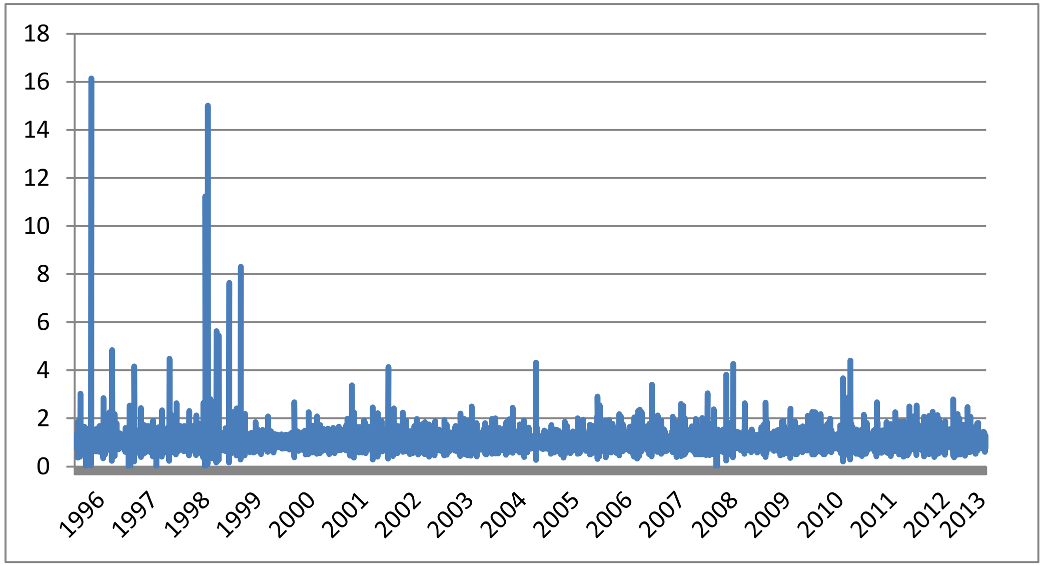
KRW



MYR



SGD



THB