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Heavy Tails in Foreign Exchange Markets: Evidence from Asian Countries

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Abstract

In recent years, Extreme Value Theory (EVT) has been proposed to deal with the heavy tailed distributions. This paper introduces *L*-moments and *L*-moment ratios based on EVT to analyze the distributional characteristics of exchange rates, and furthermore introduce the Kappa (κ) distribution to analyze the effects of globalization by understanding differences and similarities among Asian countries and developed countries before and after the crisis. We classify the behavior of exchange rates of East Asian countries and several financially developed countries into groups: the EURO zone, UK, Japan and some Asian countries. These entire groups have experienced the same or similar shocks during credit crunch in 2008; however the responses to the event for each group are different.

We take extreme value point of view to analyze the effects of globalization by examining the exchange rates. For this purpose, we calculate the so called *L*-moments and *L*-moment ratios. Based on these estimates, we implement structural break test based on Kappa distribution showing the different aspects of the analyses. The most striking features are the different shape of *L*-moments and the coefficients of κ distribution among each group, and a closer examination of the *L*-moments diagram and parameters before and after the credit crunch in 2008 will reveal the different responses on the crisis and implications of the globalization.

The results obtained by examining the behavior of exchange rate returns may be pertinent to economic policy making and macroeconomic forecasting. The finding that exchange rates of several Asian countries are typically more heavy-tailed than those of developed counterparts may reflect their susceptibility to more frequent and extreme external and internal shocks. The empirical results may also indicate that behavior of the distribution of extremes in Asian countries is time variant with a tendency to become fatter tailed during turbulent periods. Analysis on currency markets based on Kappa distribution shows that before financial crisis, South Korea, Taiwan and UK have relatively low second shape parameter than other countries. However, after the mortgage crisis, the parameters of all countries are close to 2. Therefore, we may say that after 2008, the distribution of all countries converge. From this we may conclude that before crisis, South Korea and Taiwan may not manage exchange rate market as others does, but after crisis, South Korea and Taiwan have sufficient power to manage exchange rate. Through the efforts to overcome global crisis, East Asian countries start to share the common feature of exchange rates with financially well developed countries around financial crisis.

JEL Classifications: C02, F65, G15

Keywords: emerging markets, exchange rate, *L*-moments, Kappa (κ) distribution, Extreme Value Theory (EVT)

1. Introduction

Although it is often assumed that financial market returns follow the normal distribution, there is a lot of empirical evidence that the distribution of financial market returns tends to have fatter tails than those implied by the normal distribution. Mandelbrot (1963) was one of the first to notice that financial market turbulence cannot be captured by the normal distribution function. Specifically, he has found that tail probabilities seem to exhibit a 'heavy' tails in contrast to the exponential tail decays of so-called 'thin-tailed' distribution such as the normal distribution.

In recent years, Extreme Value Theory (EVT) has been proposed to deal with the heavy tailed distributions. It focuses only on large price movements and their associated probabilities by directly studying the tails of probability distributions. In particular, it investigates the distribution of the maximum (minimum) in samples, thereby determining the shape of the tail of the distribution. The limit law for the maximum is characterized by the so-called tail-index α, which corresponds to the number of existing moments of the underlying distribution (See Embrechts, Klüppelberg, and Mikosch (1997) for the details of EVT).

Meanwhile, the precise modeling of the empirical distribution of financial market returns is of crucial importance not only for estimating risk measures such as Value at Risk (VaR) and Expected Shortfall (ES) but also for the robustness of many economic models, leading, in a number of settings, to reversals of conclusions drawn from them (See for example Ibragimov, Ibragimov, & Kattuman, 2013). It is well known that stock markets can be described by heavy tailed distribution with tail parameter 3.1 ± 0.1 all over the world (Gabaix, Gopikrishnan, Plerou, & Stanley, 2003). One possible explanation for this observation is that these markets are relatively well regulated and transparent. However, foreign exchange markets are quite different in the sense that their heaviness of return distribution is apparently different from industrialized countries and emerging countries (See for example, Ibragimov *et al.* (2013) for recent study and the references therein). Also, the regulations and monetary policies on these markets and transparency are quite different from the stock markets.

The novelty of this paper is to introduce relatively new analytic tools in this field of study. To be specific, we introduce *L*-moments and *L*-moment ratios, which have been quite popular in the hydrology, to analyze the distributional characteristics of exchange rates, and furthermore introduce the four parameter Kappa (κ) distribution to analyze the effects of globalization by understanding differences and similarities among Asian countries and developed countries before and after the crisis.

We start by examining the behavior of exchange rates of East Asian countries and several financially developed countries, and classifying them into several groups: the EURO zone, GBP, Japan and finally Asian countries. These entire groups have experienced the same or similar shocks during credit crunch in 2008; however the responses to the event for each group are different. In this paper, we take extreme value point of view to analyze the effects of globalization by examining the exchange rates. For this purpose, we calculate the so called *L*-moments and *L*-moment ratios. Based on these estimates, we implement several empirical tests to understand differences and similarities among Asian countries and developed countries. Structural break test based on Kappa distribution shows the different aspects of the analyses. The most striking features are the different shape of *L*-moments and the coefficients of κ distribution among each group, and a closer examination of the *L*-moments diagram and parameters before and after the credit crunch in 2008 will reveal the different responses on the crisis and implications of the globalization.

The following sections are as follows. In section 2, we introduce the theoretical background of L-moments and Kappa (κ) distribution. The empirical results on structural break and the stability of currency markets are provided in section 3. And we provide the concluding remarks in the last section.

2. Theoretical Background

2.1. L-moments[1]

L-moments are an alternative way to describe the probability distributions. Historically they are understood as modifications of probability weighted moments, which were first introduced by Greenwood, Landwehr, Matalas, and Wallis (1979). Probability weighted moments of a random variable X with cdf $F(x)$ are defined as

$$M_{r,p,s} = E[X^p[F(X)]^r[1-F(X)]^s].$$

The most useful cases are the probability weighted moments $\alpha_r = M_{1,0,r}$ and $\beta_r = M_{1,r,0}$. If a distribution has a quantile function, $x(u)$, then by quantile transformation

$$\alpha_r = \int_0^1 x(u)(1-u)^r du \ , \qquad \beta_r = \int_0^1 x(u)u^r du$$

Now we define the L-moments of X to be the quantities

$$\lambda_r = \int_0^1 x(u)P_{r-1}^*(u)du,$$

where $P_r^*(u)$ is so-called shifted Legendre polynomial, which has the explicit form

$$P_r^*(u) = \sum_{k=0}^{r} p_{r,k}^* u^k = \sum_{k=0}^{r} (-1)^{r-k} \binom{r}{k} \binom{r+k}{k} u^k.$$

In general, L-moments are given, in terms of probability weighted moments, by

$$\lambda_{r+1} = (-1)^r \sum_{k=0}^{r} p_{r,k}^* \alpha_k = \sum_{k=0}^{r} p_{r,k}^* \beta_k$$

It is convenient to define dimensionless versions of L-moments by dividing the higher-order L-moments by scale measure λ_2. Then, the L-moments ratios are defined by

$$\tau_r = \frac{\lambda_r}{\lambda_2} \ , \qquad r = 3,4,\cdots$$

which measure the shape of a distribution independently of its scale of measurement.[2]

The most important properties of L-moments are the existence of all moments ($r > 1$) and uniqueness under the assumption of the existence of the first moment. That is, unlike the

[1] This section heavily draws on Hosking and Wallis (2005).

[2] The L-moments, up to 4th order, contain information about the location, the scale, or the dispersion, the skewness and the kurtosis of the distribution, respectively. However, these moments are scale dependent so that the comparison analysis with these L-moments may mislead. Hosking and Wallis (2005) suggest the L-moment ratios, which measure the shape of a distribution.

conventional moments of a random variable, if the mean of a random variable exists, all of the *L*-moments exist; moreover, the *L*-moments uniquely determine the distribution.

2.2. Kappa (κ) Distribution

As we have discussed above, normal distribution have showed poor performance in explaining the movement of finance/macroeconomic variables, especially when the economy was in the unstable mood. Therefore, we have to employ another approach which can overcome the weak point of using normal distribution. One candidate is using the distributions with more than 2 parameters such as generalized logistic, (hereafter GLO), generalized extreme-value, (hereafter GEV), generalized Pareto distributions, (hereafter GPD) and Kappa (κ) distribution. As we have seen above, these distributions can explain extreme values which are observed frequently during financial crises. Among those distributions, κ distribution is the most generalized distribution and therefore, we will use κ distribution to analyze the movement of exchange rates.

The κ distribution is a four-parameter distribution that includes as special cases GLO, GEV and GPD. The four parameters are location parameter, ξ, scale parameter, α, and shape parameters, k and h. The PDF and CDF of distribution are as follows. [3]

$$f(x) = \frac{1}{\alpha}\left\{1 - \frac{k(x-\xi)}{\alpha}\right\}^{\frac{1}{k}-1} \{F(x)\}^{1-h}$$

$$F(x) = \left[1 - h\left\{1 - \frac{k(x-\xi)}{\alpha}\right\}^{\frac{1}{k}}\right]^{\frac{1}{h}}$$

There are several ways to estimate the parameters of κ distribution such as moment estimation, *L*-moment estimation and maximum likelihood estimation. The method of moments involves equating the sample moments to the population moments which, in turn, are functions of the unknown parameters. Although for most distributions moment estimators can be obtained relatively easily, they are often poor estimates, particularly in small samples. Also, the estimation method is restricted the region where the moments up to 4th order exists. MLE is most widely used method because of its desirable properties such as consistency, asymptotic efficiency and normality. However, the probability density function of κ distribution is quite complex so that it is hard to get the stable estimates. *L*-moment estimation provides an alternative method of estimation analogous to conventional moments, but with several advantages, including more robust estimates with less bias. Also, it is usually computationally more tractable than maximum likelihood estimates and less

[3] A two parameter distribution with a location and scale parameter plots as a single point on the *L*-moment diagram, because two distributions that differ only in their location and scale parameters are distributions of random variable X and $Y = aX + b$ with $a > 0$, and these random variables have the same *L*-skewness and *L*-kurtosis. A three parameter distribution with location, scale and shape parameters plots as a line, with different points on the line corresponding to different values of the shape parameter. Distributions with more than one shape parameter generally cover two-dimensional areas on the graph. The cases $h = 0$ and $k = 0$ can be explained as the continuous limit case. Also, the three-parameter Kappa distribution of Mielke and Johnson (1973) is a special case of the kappa distribution defined as follows.

$$F(x) = \left(\frac{x}{b}\right)^{\theta}\left\{a + \left(\frac{x}{b}\right)^{a\theta}\right\}^{-\frac{1}{a}}, \qquad x \geq 0, \qquad a, b, \theta > 0,$$

where $\xi = b$, $\alpha = \frac{b}{a\theta}$, $k = -\frac{1}{a\theta}$ and $h = -a$.

restricted than moment estimation because the existence of the first moment guarantees the existence of other higher moments. Therefore, among these approaches, we use *L*-moment approach.

3. Empirical Analysis on Structural Break and Currency Market Stability

For the analysis in this paper, we use the exchange rates of several countries, which are maintained and published by Federal Reserve Bank of Saint Louis.[4] We use weekly data for estimation of parameters and among several countries, we pick four Asian countries, Japan, South Korea, Singapore and Taiwan and United Kingdom and Euro area, totaling 6 countries. The sampling period is from January 1999 to June 2014. The estimated *L*-moments and *L*-moment ratios, or τ, are as follows.

Table 1. Sample *L*-moments and *L*-moment ratios of countries in the analysis. λ_r represents the r-th order *L*-moment and τ_r represents the r-th order *L*-moment ratios, which is defined as $\frac{\lambda_r}{\lambda_2}$

Country	$\boldsymbol{\lambda_1}$	$\boldsymbol{\lambda_2}$	$\boldsymbol{\tau_3}$	$\boldsymbol{\tau_4}$
Japan	-0.00011	0.00628	-0.03349	0.14309
South Korea	-0.00017	0.00604	0.08413	0.29171
Taiwan	-0.00009	0.00263	0.01529	0.24775
Singapore	-0.00036	0.00314	0.05185	0.18830
Euro	-0.00019	0.00643	0.02026	0.14257
UK	-0.00002	0.00574	0.05597	0.17741

First, we note that all of the first *L*-moment (which is exactly the same as the conventional first moment) of these countries are less than zero, which implies that these countries' currencies are getting stronger than dollar during this period. However, the amount of currency appreciation across countries is different. To be specific, Singapore got more power than other countries in view of US dollar whereas the Pound, the currency of United Kingdom, got little power. Regarding the second parameter, we may say that the variances of currencies are country specific so that we cannot distinguish the emerging market and financially developed market in view of scale parameters.

The last two columns of Table 1 show that the shape of distributions are also country specific. Interesting point is that all the countries have positive skewness except Japan. Whereas we cannot find the notable differences between Asian and developed countries in view of skewness, South Korea and Taiwan show relatively larger kurtosis than developed countries. From this, we may conclude that these two countries may have fatter tail than developed countries. The figure 1 shows the feasible region for κ distribution and other distributions on the *L*-moments diagram. (See the footnote 3 for the interpretation of the *L*-moments diagram).

According to Figure 1, the closest possible distributions to our data are GLO and GEV. It implies that our data may share the common characteristics of these distributions.[5] Therefore, we

[4] Nominal exchange rate is defined as the country's own currency to United States' Dollar. So, we have modified the nominal exchange rate by inverting it when the exchange rate provided by Fed is dollar to country's own currency.

[5] Approximating our data with these distributions is plausible approach because these distributions are simpler than κ distribution. However, it does not imply that the fourth parameter of κ distribution, h, is near -1.

may say that the distribution of exchange rate return has upper fat tail. This symptom is easily observed and called as overshooting.[6] If the parameters are different across countries, the amount of surge in exchange rate will be also different. So, we need to estimate the parameters from this data set.

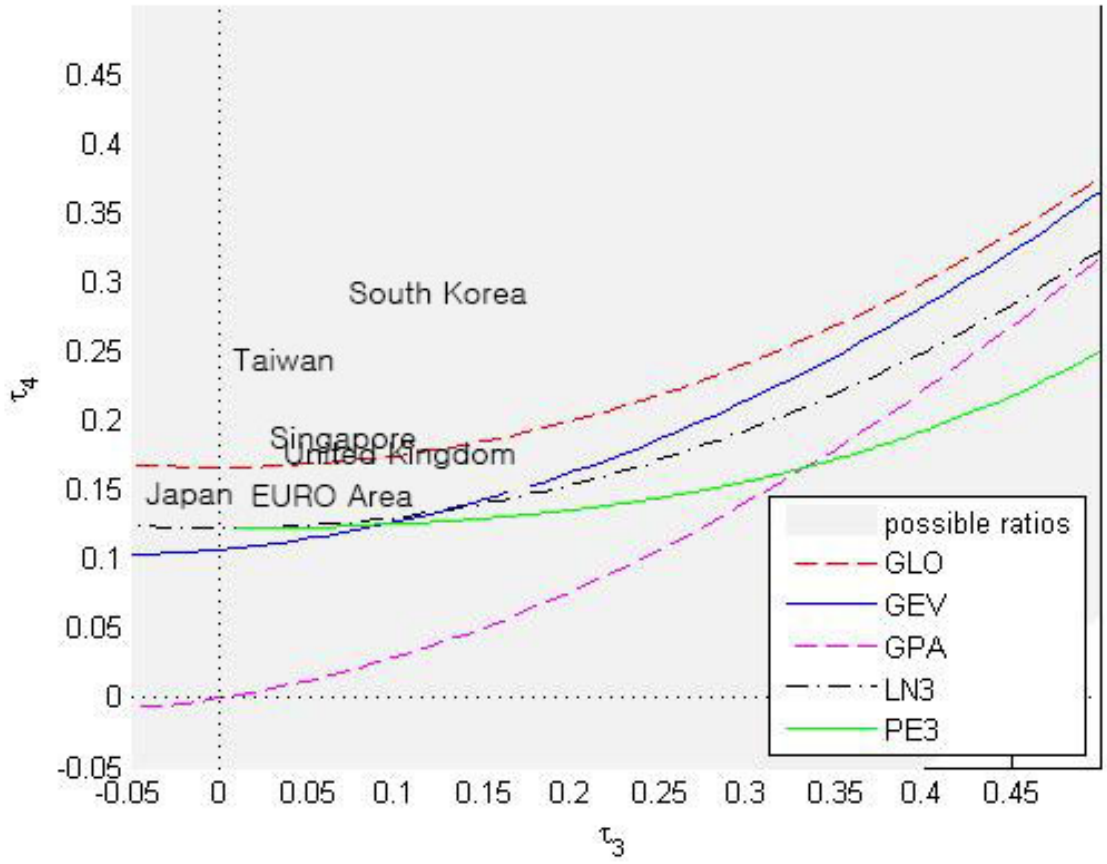


Figure 1. The feasible region and sample moments of countries in the analysis

Among several methods, we will use *L*-moment estimation to get the parameters of κ distribution. The parameters of many distributions can be represented by the combination of *L*-moments. However, unlike other distributions, κ distribution has no simple expression for the parameters in terms of *L*-moments. Therefore, we have to lean on numerical iterating method. We will change the parameters until these two shape parameters can satisfy the expressions for τ_3 and τ_4.[7] Given these

[6] Although many theoretical reasons are provided to explain these overshooting phenomena, none of them dominate others. However, we can observe a surge in exchange rate frequently especially during crisis so that a steep increase in exchange rate at crisis state is a stylized fact in finance.

[7] The Fortran code suggested by Hosking (1996) used Newton-Raphson method to get the parameters. Unfortunately, this algorithm does not satisfy the global minimum condition so it cannot guarantee the unique relationship between parameters and *L*-moments. (This symptom has been observed through many papers. Park & Jung (2002) is one of them.) In such cases, the program returns the solution for which the h parameter is largest. Therefore, we modified this approach by using 'interior-point method' supported by Matlab with sufficient iteration steps and with different initial values. And then, the program returns the solution for which the objective function is smallest.

two shape parameters, we can calculate the other two parameters, namely location and slope parameters. Table 2 is the estimated results.

Table 2. Estimates of κ distributions for countries in the analysis
(ξ is the location parameter, α is the scale parameter, k and h are shape parameters)

Country	$\boldsymbol{\xi}$	$\boldsymbol{\alpha}$	$\boldsymbol{k}$	$\boldsymbol{h}$
Japan	0.00059	0.01128	1.01956	2.21354
South Korea	0.00198	0.00400	0.73535	1.07703
Taiwan	0.00048	0.00239	0.87243	1.16236
Singapore	0.00048	0.00509	0.94358	2.14512
Euro	0.00105	0.01093	0.97800	2.16717
UK	0.00150	0.00931	0.94347	2.14111

All the parameters we get are positive and these distributions cannot be one of the special cases.[8] Also, based on shape parameters, we can see the difference between several East Asian countries and financially developed countries. The financially developed countries and some East Asian countries which manage the exchange rate well such as Japan and Singapore have higher h than that of East Asian countries which have experienced currency crisis during our sample period.[9] It implies that crisis experiencing countries may have fatter tail than other countries. Hereafter, we will call FOUR countries to represent Japan, Singapore, Euro Area and UK and TWO countries to represent South Korea and Taiwan.

3.1. Structural Break Test

Exchange rate is one of the key macroeconomic/financial variables and it is well known that the exchange rate is closely related with other key variables such as price level, interest rate, and GDP among many others. As a natural consequence, the exchange rate generating process may change over time as the international economic environment fluctuates. We already notice that Asian countries' exchange rate and some developed countries' exchange rate have experienced severe crisis such as 1997 currency crisis and 2008 subprime mortgage crisis. Therefore, it might be interesting to check whether we are able to detect the structural break of exchange rate generating process through our analytical tools.

There have already been several different methodologies suggested to test the structural break(s) of time series datasets in the literature. To test the structural break in exchange rate generating process in this paper, we stick to the concept of *L*-moments, therefore we calculate the *L*-moments with moving windows, whose size is 104, which implies that *L*-moments were calculated based on 2 years sample period. Based on this, we obtain the τ_3 and τ_4. We define that $\tau_{s,before}$ and $\tau_{s,after}$ where $s = 3,4$ as τ variables before and after structural break point, respectively.

[8] The parameter, h, determines the shape of distribution. If h is equal to -1, 0 and 1, then κ distribution is represented as GLO, GEV and GPD. h is none of these cases so that a κ distribution cannot be one of these extreme value distributions. However, we may say that distribution is close to GPD in a graphical view.

[9] South Korea has experienced the financial crisis by mortgage crisis, originating from USA and Taiwan has experienced surges in exchange rate at 2001 and 2008 due to shrink in semi-conduct market and mortgage crisis, respectively.

The purpose of this experiment is just to confirm the usefulness of the *L*-moments and the related distributional analysis, not to replace the existing structural break test methodologies. The null hypothesis is very simple, $\tau_{s,before} = \tau_{s,after}$, which implies that there is no structural change among τ 's. The alternative hypothesis is that at least one of them changes. We set the structural break point as January, 2008. The reason why we set this as structural break point is that, as we all know, whole world financial market were sacrificed by subprime mortgage crisis, originating from US.[10] The results are that all of the *p*-values are zeros and we may conclude that exchange rate generating process changes at January, 2008 as we expected.

As we have seen above, the *L*-moments are closely related with parameters of κ distribution. Therefore, we can easily infer that there is also a structural break in parameters of the distribution. Table 3 shows the coefficients estimated by *L*-moment method with the data which lies before and after structural break point.

Table 3. Estimates of κ distribution with prior to and after 2008

Country	$\boldsymbol{\xi}$	$\boldsymbol{\alpha}$	$\boldsymbol{k}$	$\boldsymbol{h}$
Japan	0.001 / 0.001	0.012 / 0.011	1.032 / 1.009	2.213 / 2.214
South Korea	-0.002 / 0.003	0.009 / 0.011	1.200 / 0.889	1.460 / 2.128
Taiwan	0.001 / 0.000	0.002 / 0.005	0.846 / 0.984	1.144 / 2.201
Singapore	0.001 / 0.000	0.005 / 0.005	0.968 / 0.925	2.163 / 2.128
Euro	0.001 / 0.001	0.012 / 0.010	1.010 / 0.953	2.186 / 2.152
UK	-0.002 / 0.002	0.010 / 0.010	1.187 / 0.929	1.447 / 2.132

Note: The parameters which lie in the left side of slash are the coefficients with data before structural break point and the parameters which lie in the right side of slash are the coefficients with data after structural break point

This table gives us some clues to understand the big picture of each country's capability of managing its own exchange rate before and after the crisis. First we focus on the second parameter α , which represents the dispersion of the distribution. The second parameters of FOUR countries decrease or, at least, equal. However, the second parameters of TWO countries increase. From this, we may say that FOUR countries show relatively good performance in managing volatility of exchange rate due to mortgage crisis whereas TWO countries do not, at least in terms of distributional point of view.

The last two shape parameters seem to be more interesting to us. Regarding the third parameters, they decrease after subprime mortgage crisis except Taiwan and it stays around 1. Regarding the fourth parameters, before financial crisis, TWO countries and UK have relatively low parameters than other countries. However, after the mortgage crisis, the parameters of all countries are close to 2. Therefore, we may say that after 2008, the distribution of all countries converge. From this we may conclude that before crisis, TWO countries may not manage exchange rate market as others does, but after crisis, TWO countries have sufficient power to manage exchange rate. Therefore, all the East Asian countries start to share the common feature of exchange rate with financially well developed countries around financial crisis through globalization.

[10] Most of emerging markets have experienced sudden stop at these moments and the discrepancy between demand and supply of domestic currency, due to the outflow of foreign fund, caused the surge in exchange rate. To handle this situation, most of emerging countries increased the supply of foreign currency in the market by using foreign international reserves.

Here, we would like to point out the difference between Singapore and TWO countries, Taiwan and South Korea. Singapore is one of main Asian financial hub and to stabilize the exchange rate, it accumulates a large amount of international reserves even more than its annual GDP. As we all know, the amount of international reserves is one of major factor which can stabilize the exchange rate. Therefore, Singapore can support stable exchange rates. However, the other Asian countries we picked are major exporting countries. So, the exchange rate is affected not only by financial transaction, but also by exports. This feature causes a difficulty in managing exchange rate for TWO countries.

3.2. Static Stability of Currency Market

The main objective of monetary authority regarding exchange rate is to stabilize the exchange rate regardless of exchange rate regime. Therefore, although there are several countries which stay on floating exchange rate regime, these countries frequently intervene the currency market to avoid a surge in exchange rate. However, it is not easy for us to forecast the effect of exchange rate related policy because, unlike other policies, exchange rate related policies are not easily observed by public. To be specific, monetary authority plays a role as one of market participant among traders so that the effect of exchange rate related policy is affected by the market participants' anticipation. For example, the trader who participate in the high fluctuating market give relatively less attention to a surge in exchange rate as the traders who participate in more stable market do. Therefore, it is important to know the currency market's stability.

To see this, we re-estimate the parameter of κ distribution after adding the shock at the end of period. The shock level we have used is 50%. If the parameter changes, it implies that the currency market is vulnerable to external shock and monetary authority should intervene immediately to stabilize the exchange rate whereas monetary authority should respond to external shock with hesitation if the parameter is stable. Table 4 is the estimated results.

Table 4. Estimates of κ distribution with 50% exchange rate surge shock

Country	ξ	α	k	h
Japan	-0.00130	0.01053	1.14829	1.39481
South Korea	0.00205	0.00914	0.89677	2.12602
Taiwan	0.00058	0.00430	0.95329	2.17890
Singapore	0.00048	0.00509	0.94358	2.14512
Euro	0.00031	0.00752	0.98135	1.25548
UK	-0.00108	0.00956	1.14242	1.39849

As we have seen above, the lower fourth parameter (h) implies more vulnerable exchange rate regime and the estimated fourth parameter of Japan, Euro area and UK drop down to 1.2/1.3, whereas that of South Korea, Taiwan and Singapore stays around 2. It implies that the 50% surge shock in currency market may cause market turmoil in these countries which are classified as financially developed countries. Therefore, financially developed countries should intervene the exchange rate market immediately whenever a surge in exchange rate is observed.[11]

[11] *L*-moments approach is known as one of the robust estimation methods. That is because higher *L*-moment can be calculated as long as the first *L*-moment can be obtained, which is the average of sample data and these *L*-moments are so robust to abnormally large or small variables. Therefore, the effect of shock on parameters is restricted if we estimate the parameters with *L*-moment estimation method. So, the result what we have got supports our remark very well.

In other words, financially well developed countries cannot endure a large amount of surge in exchange rate whereas those countries which have experienced several crises were not so much affected by that. However, it is important to note that this analysis does not imply that those countries with severe experiences can handle the unexpected situation effectively, but it just shows that the participants of those markets are immunized to such an irrational shock.

Now, we examine the market's stability in a different view. If the market is more unstable, then the high probability corresponding value of exchange rate's return will be higher. We set the critical values as follows, 50%, 70%, 90%, and 95%. Based on these probabilities, we calculate the critical values of countries which are corresponding to these probabilities. Table 5 shows the results.

Table 5. Critical values of each country assuming a 50% surge in exchange rate

Country	50%	70%	90%	95%
Japan	0.00781	0.00900	0.01066	0.01114
South Korea	0.00814	0.00931	0.01102	0.01157
Taiwan	0.00340	0.00389	0.00461	0.00484
Singapore	0.00381	0.00442	0.00529	0.00556
Euro	0.00813	0.00937	0.01112	0.01165
UK	0.00759	0.00870	0.01030	0.01079

As we can see above, the values are quite high regarding the negative and near zero first L-moment value. Also, Taiwan and Singapore show relatively small numbers, which is almost a half of other countries' values.[12] From this, we may have the following implication. Although monetary authorities have same attitudes across countries, they will intervene the market with different tolerance levels.

3.3 Dynamic Stability of Currency Market

In the previous subsection, we have used the whole period sample. However, in monetary authorities' perspective, the dynamic characteristics of exchange rate are more proper statistics than the static characteristics of exchange rate. That is because the policy should be implemented in a timely manner. Also, we already have shown that the parameter of κ distribution changes after experiencing crises. From this, we may infer that the shock may have a different influence on foreign currency market although the size of external shocks is exactly same. In this perspective, we will calculate what we have done above; namely, time varying L-moments and critical values.

First, we will examine the time-varying L-moments. In a previous section, we calculate L-moment ratios, or τ, by using whole sample and the ratios are gathered. However, if we calculate these ratios by using subsample with changing window, we may see the time-varying ratios and fluctuation of exchange rate more precisely. The following Figures, figure 2 and figure 3, show the time-varying L-moment ratios.

As we can see, South Korea and Taiwan show relatively large fluctuation whereas the rest of countries show stable fluctuation over time. As we all know, South Korea and Taiwan have experienced several currency crises such as 1997 currency crisis and 2008 subprime mortgage crisis. Although other Asian countries such as Singapore and Japan have affected by these external

[12] Considering that two shape parameters are quite similar among countries, this result comes from the location and slope parameters.

currency shocks, they overcome with a large amount of international reserves.[13] That is why these two countries may have relatively smaller deviation of τ ratios than Taiwan and South Korea do.

In addition to this, we may find the difference in response to external shocks between Taiwan and South Korea. To see this more closely, we plot the time varying *L*-moments ratios of each country. So as to show the difference between before and after currency crisis at 2008, we have used different colors, namely, blue for before crisis, green for after crisis (See figure 2).

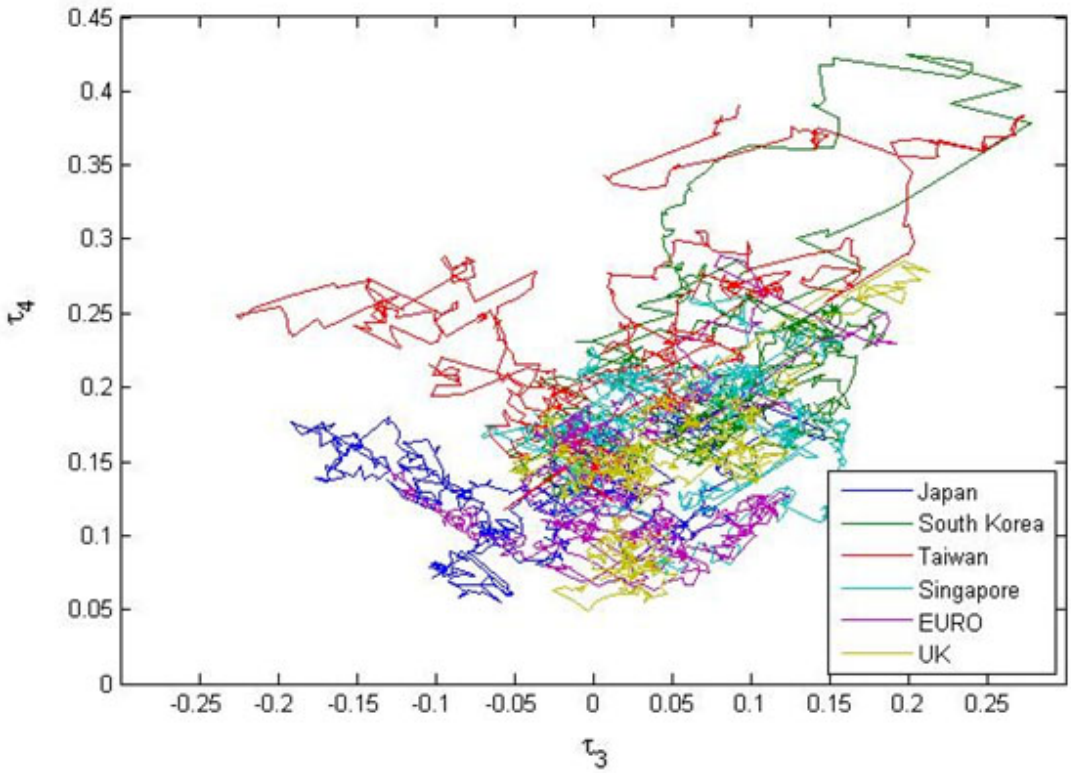
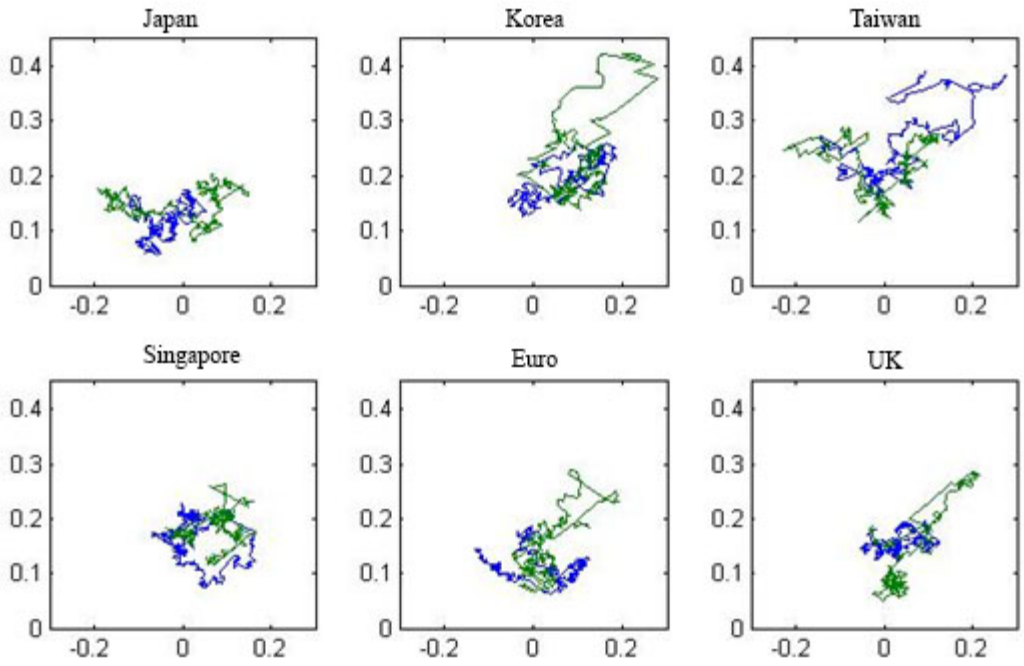


Figure 2. Sample *L*-moments ratios of countries in the analysis

From figure 3, we may find that the deviation of Taiwan before structural break point is larger than that of South Korea whereas the response of South Korea after structural break point is larger than that of Taiwan. Also, the financially well developed countries show the increase in both τ variables after structural break point and South Korea does. However, the τ variable of Taiwan moves oscillates left and right similar to that of Japan. From this, we may conclude that South Korea is getting coupled with financially well developed countries rather than Asian countries whereas Japan and Taiwan are getting decoupled with these countries by overcoming external shocks.

Let's see this with time-varying critical points. As we have pointed out, the *L*-moments have strong relationship with parameter and the critical points are determined by parameters so that we can easily infer that critical values will be time-varying as the *L*-moments do. Figure 4 supports this statement.

[13] Japan is the second country which accumulate large amount of international reserves and Singapore accumulate international reserves more than its annual GDP.



(Blue line represents the data prior to 2008 and green line is for the data after 2008)

Figure 3. The time varying *L*-moments ratios of the countries in the analysis

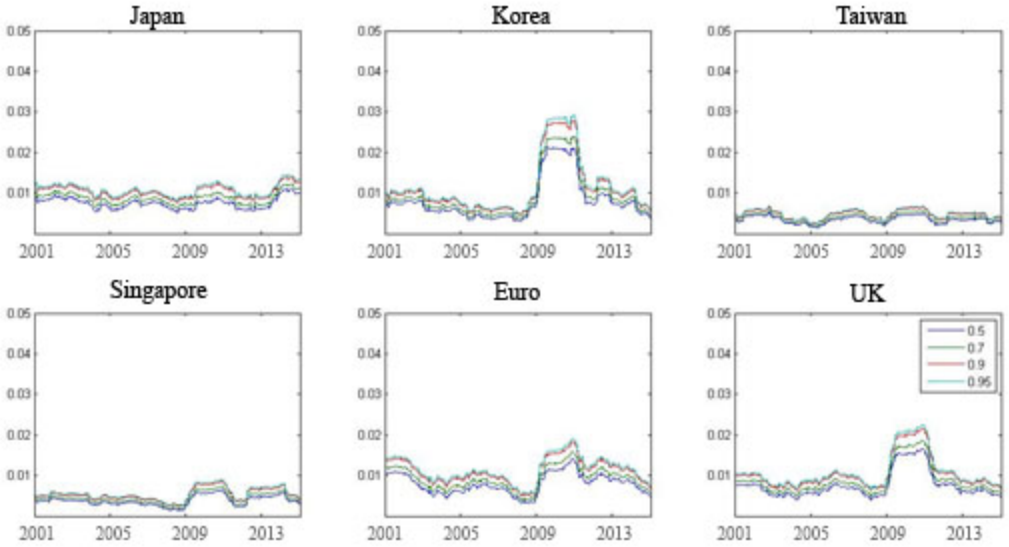


Figure 4. Time-varying critical values of countries in the analysis

We note the shape of distributions due to shock after 400 to 459 is similar except the magnitude. UK and South Korea resembles each other although the magnitude of South Korea is higher. After financial crisis, Singapore and Japan looks similar. Unlike other financially developed countries, the effect of shock still remains even though one year has passed after the occurrence of crisis.

From this figure, we may find that South Korea and Taiwan have several spikes. The different thing between these two is the location of spikes: South Korea has these things around 2008 whereas the Taiwan around 2001. At 2008, as we have point out above, subprime mortgage crisis happened so we may say that South Korea was affected by subprime mortgage crisis. At 2001, there was a 9/11 attacks and the global semi-conduct market shank 13.5%. Taiwan is one of major semi-conduct product exporting countries and is vulnerable to technology shock. Therefore, we may conclude that Taiwan was affected by several external shocks.

4. Concluding Remarks

In this paper, we introduce relatively new analytic tools based on Extreme Value Theory (EVT) in this field of study. In particular, we introduce *L*-moments and *L*-moment ratios, which have been quite popular in the hydrology and climatology, to analyze the distributional characteristics of exchange rates, and also introduce the four parameter Kappa (κ) distribution to analyze the effects of globalization by understanding differences and similarities among Asian countries and developed countries before and after the crisis. We classify the behavior of exchange rates of East Asian countries and several financially developed countries into groups. These groups have experienced the same or similar shocks during credit crunch in 2008; however the responses to the event for each group are different.

We take extreme value point of view to analyze the effects of globalization by examining the exchange rates. For this purpose, we calculate the so called *L*-moments and *L*-moment ratios. Based on these estimates, we implement structural break test based on Kappa distribution showing the different aspects of the analyses. The most striking features are the different shape of *L*-moments and the coefficients of κ distribution among each group, and a closer examination of the *L*-moments diagram and parameters before and after the credit crunch in 2008 will reveal the different responses on the crisis and implications of the globalization.

The results obtained by examining the behavior of exchange rate return may be pertinent to economic policy making and macroeconomic forecasting. The finding that exchange rates of several Asian countries are typically more heavy-tailed than those of their developed counterparts may reflect their susceptibility to more frequent and extreme external and internal shocks. The empirical results may also indicate that behavior of the distribution of extremes in Asian countries is time variant with a tendency to become fatter tailed during turbulent periods. In addition to this *L*-moment related analysis, we analyze the currency market with κ distribution. From this analysis, we may say that before financial crisis, South Korea, Taiwan and UK have relatively low second shape parameter than other countries. However, after the mortgage crisis, the parameters of all countries are close to 2. Therefore, we may say that after 2008, the distribution of all countries converge. From this we may conclude that before crisis, South Korea and Taiwan may not manage exchange rate market as others does, but after crisis, South Korea and Taiwan have sufficient power to manage exchange rate. Therefore, finally we may say that through the efforts to overcome global crisis, East Asian countries start to share the common feature of exchange rate with financially well developed countries around financial crisis.

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