DYNAMIC INTERACTION AMONG ASIAN EXCHANGE RATES: EVIDENCE FROM ASIAN FINANCIAL CRISIS

By

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ABSTRACT

This paper examines the pattern of interaction among Asian exchange rates, and how the pattern changed before and during/after the Asian financial crisis of 1997-98. The empirical tests are conducted using daily nominal exchanges rates based on the US dollar and the Japanese yen from several Far East countries and Australia during pre crisis period (1990-1997) and during/after crisis period (1997-2002). The empirical tests are conducted using Johansen multivariate cointegration method and band spectrum regressions. Results from both tests indicate substantial changes in the interaction and relationships between the Far East exchange rates before and after the crisis. Results from the band spectrum regressions indicate the increase in the domination of the US dollar in the region after the crisis.

JEL Classification: F40, F41

Key Words: Exchange Rate, Asian Financial Crisis, Johansen Cointegration, and Band Regression

1. Introduction

The Asian financial crisis that began in 1997 is similar in character to the October 1987 crisis. Both crises were triggered in one country and spread quickly to other countries, and had a cumulative effect on the economies. However, unlike the October 1987 crisis, the Asian financial crisis was triggered by a currency crisis. It began with July 2nd Thai Baht's crash, followed by currency depreciation in other Asian countries and then coincided with the stock market crash. The spread of crashes, which is referred to as contagion effect in the literature, had extended further to other emerging and major markets.

The interaction among national stock markets during the period of crisis has been intensively examined (for example, Jeon and Furstenberg (1990), Malliaris and Urrutia (1992), and Arshanapalli and Doukas (1993)). However, relatively little research effort has been directed at examining the evidence in foreign exchange markets. Recent works have been done on linkage among Asian foreign exchange markets are Sarwar (1997) and Chan et al (1997). Both papers investigated the cross-section efficiency of several Asian black exchange. But the interaction pattern of Asian exchange rates has not been thoroughly explored. It is the purpose of this paper to examine the pattern of interaction among Asian exchange rates, and how the pattern changed before, during and after the crisis. According to McKinnon (1991) and Eichengreen (1992) the nature of the international linkages among currencies is a matter of considerable interest to governments in general, financial markets and corporations in particular. The stability of exchange rates could largely mitigate currency risk and lead to more integrated financial markets, equally among interest rates and possibly eliminate the current account imbalances among trading countries.

Most of the Far East countries that experienced the effects of the financial crisis went through an exchange rate regime change after the crisis was over. Given the dramatic effect of the crisis on the exchange rates and the change in the regime after the crisis, it is of interest to check for change in the pattern of interaction between the Far East exchange rates. This paper will be especially meaningful for the investors and policy makers to understand the interaction among Asian exchange rates before and during/after the financial crisis.

Researches in stock market around October 1987 crash generally conclude that the degree of international co-movements among stock markets has increased substantially after the crash. But the roles of Japanese market and US market are not clear. For example, while Jeon and Furstenberg (1990) find that the strong leadership of US have been reduced to Japan since the October crash, Malliaris and Urrutia (1992), Arshanapalli and Doukas (1993) argue that Tokyo plays a passive role in the crash. Similarly, in the area of foreign exchange market linkages, Mougoue (1992) find strong common trend exist between four Asian exchange rates from September 1982 to September 1989, Sarwar (1997) and Chan et al (1997) find co-movement exist between Asian black exchange markets. Contradict evidences are also found on the role of Japanese yen and US dollar. Frankel (1992), Frankel and Wei (1994), and Chinn and Frankel (1994) conclude that although yen's influence is increasing in the region, it is US dollar that has dominated the Asian markets. However, Aggarwal and Mougoue (1993) and Tse and Ng (1997) support the hypothesis of a Yen Bloc in the region. In this paper, we conduct tests with both the yen and the dollar based Far East exchange rates. In this manner the role of both the yen and the dollar in the region before and after the crisis may be investigated.

Most studies in market linkages rely solely on time domain techniques such as cointegration test. However, cointegration is suitable for detecting long run relationships, and hence the power of the test depends on the data span. Message contained in the high frequency data has been concealed (Hakkio and Rush (1991) argue that for cointegration, high frequent data does not provide more information than low frequent data using the same data span). On the contrary, frequency domain regression—Band spectrum regression developed by Hanna (1963) and Engle (1974) can separate different frequency band in the data, thus provides us new tool to analyse the short-run and long run relationship in high frequency data.

In light of the above, in this paper we extend the research in this field by two main dimensions. First, two aspects of the interaction are examined: (1) whether these exchange rates exhibit long run equilibrium and how they adjust the deviance to each other; (2) the short-run and long run impacts of Japanese yen and US dollar on Asian exchange rates respectively. Whether these interaction patterns are stable is examined before and after the crisis. Secondly, we extend the methods from time domain to frequency domain and thus gain a more thoroughly insight into the interaction patterns. Specifically, cointegration test are employed to detecting the long run relationship, and band spectrum regression is used to investigate the short-run and long run relationship between Asian exchange rates and the Japanese yen and US dollar respectively.

The remainder of this paper is organised as follows. Section 2 provides a discussion on the Asian financial crisis. Section 3 introduces the data and methodology used. Section 4 presents the empirical results. Section 5 provides the summary and conclusion.

2. The Asian Financial Crisis of 1997-98

According to Pesenti and Tille (2000), countries like Thailand, Malaysia, Indonesia, the Philippines and South Korea, following years of stellar performance, experienced a plunge in the external value of currencies and a sudden reversal of private capital flows from June 1997 onward. Corsetti et al. (1998) assert that, reflecting the macroeconomic conditions in the East Asian region, national stock markets and currencies came under speculative pressures in early 1997. During the spring of 1997, the currency of Thailand, the baht, started experiencing severe speculative pressure. Thailand had the weakest economic fundamentals in the region. Once the baht started to depreciate in July 1997, the currencies of Malaysia, Indonesia and the

Philippines with economic fundamentals and export structure similar to those of Thailand also came under speculative pressure. By the end of October 1997, the baht had depreciated relative to the US dollar by 55% below its January 1997 level; similarly the rupiah (Indonesia) fell by 54%, ringgit (Malaysia) by 34%, peso (Philippines) by 33% and won (South Korea) by 14% (Corsetti et al. 1998). Initially South Korea was the least affected. This was mainly because South Korea has the strongest economic fundamentals and different export structure among the five countries under consideration. By the end of the summer of 1997, the combined effective devaluation for the currencies of the stated five countries had a strong negative impact on the other countries in the region, such as Taiwan, Hong Kong and Singapore. By early 1998 the appreciation of the United States dollar relative to the currencies of Thailand, Malaysia, the Philippines, South Korea and Indonesia reached 78%, 52%, 52%, 107% and 151% respectively.

According to Corsetti et al. (1998) two main reasons have emerged for the Asian financial crisis of 1997-98. The first reason suggests that sudden shifts in market expectations and confidence were the main causes for the initial financial turmoil, its propagation over time and regional contagion. Based on Radelet and Sachs (1998) the crisis of 1997-98 should not be attributed to deterioration in fundamentals, but rather to panic on the part of domestic and international investors, reinforced to some extent by the failed policy response of the International Monetary Fund and the international financial community. According to the second reason the financial crisis reflected structural and policy distortions in the countries of the region (Corsetti et al, 1998). The financial crisis was triggered by a fundamental imbalance and once the crisis started, market overreaction and herding caused the plunge of exchange rates, asset prices and economic activity to be more severe than warranted by the initial weak economic conditions.[1]

3. Data and Methodology

3.1 Data

Eight Australian-Asian currencies: the Australia dollar, Singapore dollar, Malaysian ringgit, Thai baht, Indonesian Rupiah, Philippines peso, South Korean won, and Taiwanese dollar vis-à-vis the Japanese yen and vis-à-vis the US dollar are applied. The data is daily and ranges from January 1,1990 to August 30, 2002. The data is obtained from DataStream. In the remainder of this paper, the following abbreviations are used for the currencies—the AUSD, SD, MR, TB, INDR, PHP, SKW, TWD, JY and the USD. To obtain further insight into the interaction pattern among the exchange rates, the interaction pattern is examined for two sub-periods: (1) the period before the currency crash (January 1, 1990, through June 30, 1997); (2) the period including and after the currency crash (July 1, 1997, through August 30, 2002).

According to Hernandez and Montiel (2003) before the Asian crisis the currencies of Indonesia and South Korea were managed float against the US dollar. The Malaysian ringgit had limited flexibility and the Thai Baht was fixed before the crisis. After the crisis, the currencies of Indonesia, South Korea and Thailand are independently floating against the US dollar. The Malaysian ringgit has gone through few different exchange rate regimes since the crisis. The currencies of Australia, Philippines and Taiwan are independently floating against the US dollar before and after the crisis.

3.2 Johansen Multivariate Cointegration Method

[1] Further analysis of the Asian crisis may be found in Goldstein (1998) and Furman and Stiglitz (1998).

Two or more nonstationary time series are cointegrated if a linear combination of these is stationary. Cointegration tests in this paper are conducted by means of the method developed by Johansen (1988), and Johansen and Juselius (1990).[2] The Johansen method applies the maximum likelihood procedure to determine the presence of cointegrating vectors in nonstationary time series. This method detects the number of cointegrating vectors and allows for tests of hypotheses regarding elements of the cointegrating vector.[3] The Johansen maximum likelihood approach sets up the nonstationary time series as the vector autoregressive (VAR):

$$?X_t = C + S\, G_i ?X_{t-i} + ?X_{t-1} + ?D_t + ?_t \qquad ? \sim niid(0, ?) \qquad (1)$$

Where X_t is a vector of nonstationary (in levels) variables, ? implies first difference, C is the constant term and D_t is stationary series. Such stationary variables often enter as dummy variables, including seasonal dummies. The information on the coefficient matrix between the levels of the series ? is decomposed as ?=aß' where the relevant elements of the a matrix are the adjustment coefficients and the ß matrix contains the cointegrating vectors. The constant term is included in order to capture the trending characteristics of the time series involved.[4] The Johansen method provides two different tests, the trace test and the maximum eigenvalue test to determine the number of cointegrating vector(s). If a nonzero vector(s) is

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[2]. This procedure provides more robust results when there are more than two variables (Gonzalo 1994) and when the number of observations is greater than 100 (Hargreaves 1994). The Johansen procedure reveals overall the least size distortion (Haug 1996) and is still more robust than the other methods even when the errors are non-normal (Gonzalo 1994).

[3]. More detailed analysis of the Johansen procedure is provided in Dickey and Rossana (1994) and Harris (1995).

[4]. As indicated by Harris (1995) and Johansen (1992) the choice of deterministic component in the model has vital consequences for the asymptotic distribution of the rank test statistics.

indicated by these tests, a stationary long-run relationship(s) between the relevant variables is implied. Osterwald-Lenum (1992) provides the appropriate critical values required for these cointegration tests.

A likelihood ratio test and the Akaike Information Criterion (AIC) are used to select the number of lags required in the cointegration test.[5] Since there seems to be a linear trend in all the nonstationary series, cointegration tests are conducted with the inclusion of a deterministic trend.[6]

3.3 Band Spectrum Regression

Cointegration test is powerful in detecting the long run equilibrium of time series data. However, the short run interaction is only depicted by the one-step forward error correction term. It is nature to ask how exchange rates interact with each other in different short run or long run circles, as these interaction circles or oscillations are typical for price discovery process. Instead of examining data in full frequency, band spectrum regression (Hanna, 1963, Engle, 1974) disaggregates the data by different frequency bands, and thus provides more thorough insights into the interaction patterns of the exchange rates.

First, consider the simple linear regression in time domain:

$$y = \boldsymbol{a} + x\boldsymbol{b} \qquad (2)$$

It is vital in cointegration tests to determine the rank and the specification of the deterministic component of the model.

[5]. Starting with a maximum length of 12 lags, lags were eliminated if they were insignificant (as a group of 2) at the 10% level. According to Gonzalo (1994, p. 220) the cost of over parametrizing by including more lags is small in terms of efficiency but this is not true if it is underparametrized.

[6]. We checked to determine the components, and results indicated the presence of a deterministic trend. These results are available on request.

Where y and x are two exchange rates that we want to examine, and each vector contains T observations. α is a T $\times$ 1 constant vector. Since the observations are sorted by time, the regression estimator of b simply represents the relationship in full frequency.

Second, we decide the frequency band to include (exclude) in the regression. Let w denotes frequency that can be measured along the horizontal axis in radians, i.e. $0 \leq w \leq p$. Each frequency corresponds to a length of the cycle or period, that is $L = 2p / w$. For example, the frequency $w = 0.037$ corresponds to a 3 year cycle, if weekly data are used $(2 * 3.14/(56 * 3))$. The regression in the high frequency band of the frequency interval $(0, p)$ corresponds to the short-term relationship, and the regression in the low frequency band corresponds to the long run relationship. The frequency truncation point is chosen based on the sample size.

Third, the regression in the time domain is transformed into the frequency domain by a discrete Fourier transformation. Let W denotes the matrix of Fourier elements, such that

$$W_{jk} = \frac{1}{\sqrt{T}} e^{2pijk/T}$$

Where $\mathrm{j, k} = 1 \ldots \mathrm{T}$ and $i = \sqrt{-1}$. Multiplying by W and letting ~ over a variable denote its Fourier transformation, (1) appears in the frequency domain as:

$$\tilde{y} = \tilde{x}b + e \qquad (3)$$

Let A be a diagonal matrix which has ones on the diagonal for frequencies which are to be included and zeroes elsewhere. Define $x^* = W^t AWx$ which is the inverse Fourier transform of the $\tilde{x}$ after the appropriate elements are set to zero. W^t is the complex conjugate of the transpose. The least squares estimate of b , based on the transformed x^* and y^* where some frequencies are excluded, is:

$$
\begin{aligned}
ß &= (x^{t}x)^{1} x^{t}y \\
&= (x^{t}W^{t}AWW^{t}AW_{x})^{1} x^{t}W^{t}AWW^{t}AW_{Y} \\
&= (\tilde{x}^{t}A\tilde{x})^{1}\tilde{x}^{t}Ay \qquad (3)
\end{aligned}
$$

Thus we get high frequency band regression and low frequency band regression in the time domain:

$$y^{lf} = a + b^{lf}x^{lf} + e \qquad (4)$$

$$y^{hf} = a' + b^{hf}x^{hf} + e' \qquad (5)$$

Where *lf* denotes low frequency and *hf* denotes high frequency. If the degrees of significance of b are consistent in both high frequency and low frequency, we can conclude that the relationship is stable over time. If not, we can then state generally in what time band that an exchange rate heavily influence the other. In addition, if the degrees of significance of b are inconsistent in the two sub-periods, it will give us a more detailed insight of how the pattern has changed.

3. Empirical analysis and results

Table 1 provides the descriptive statistics for daily exchange rates during the two periods. It is apparent that the distributions of exchange rates were non-normal. Consistent to the literature of high frequency data, we also find evidence of significant skewness and kurtosis in the exchange rates based on both the dollar and the yen.

(Insert table 1 here)

3.1 Results of Johansen Multivariate Cointegration Test

Since cointegration tests require a certain stochastic structure of the time series involved, the first step in the estimation procedure is to determine if the variables are stationary or non-stationary in levels. The augmented Dickey-Fuller (ADF) unit root test and the Phillips-Perron unit root test are applied to check for the stochastic structure of all series. The test results show that all the exchange rates are integrated of the order one (I(1)) series, irrespective of whether the test includes a time trend or not. This is true for all series based on the yen and the US dollar during pre and post crisis periods. These results are quite standard and are not provided to save space. But, they are available on request. Given all series are I(1) we proceed with the cointegration tests.

Tables 2 and 3 show the Johansen cointegration tests using the exchange rates based on the US dollar during the pre and post crisis period. During both periods, three sets of tests are conducted. In the first test, only the Far East exchange rates are included in the VAR. In other words, the Australian dollar is not included in the VAR. Both the trace test and the maximum eigenvalue tests fail to indicate a significant vector(s) at the 5% level. Thus, during the pre crisis period (1990-1997) the exchange rates of currencies of Thailand, Malaysia, Singapore, South Korea, Taiwan, Indonesia and Philippines against the US dollar do not have a long-run stationary relationship. Adding the Australian dollar in the VAR, one significant vector is indicated by both tests at the 5% level or above. Thus, a long run stationary relationship between the exchange rates is shown only if the Australian dollar is included in the VAR. This result may indicate the importance of the Australian dollar in the region. The third test includes only the exchange rates of the ASEAN members, Thailand, Malaysia, Singapore, Indonesia and Philippines.[7] The 1967 treaty of ASEAN said the group would promote economics, social and cultural development of the region through cooperation. It

[8] The remaining members of ASEAN Bloc are Singapore, Vietnam and Brunei.

further states that the organization would be a forum for resolving economic and political differences. Given the close economic and political link between these ASEAN countries, it is possible for a long run relationship between the exchange rates of these countries. But, both the trace and the eigenvalue tests fail to show cointegration between the ASEAN exchange rates during the pre crisis period. Thus, using the exchanges rates based on the US dollar, a stationary long run relationship is only found when the Australian dollar is part of the relationship. In all cases four lags are applied in the VAR. Given most of the Far East exchange rates applied were fixed or managed fixed before the crisis, the results involving the Far East countries or the ASEAN countries may not be surprising.

(Insert Table 2 here)

Table 3 presents the cointegration tests from the period (1997-2002) that includes the crisis and the period after. In all three cases, the trace test indicates two significant vectors and the eigenvalue shows one significant vector.[8,9] Thus, all three tests results show two long-run stationary relationships between the exchanges rates. This is true whether the Australian dollar is included or not and also when just the ASEAN members are part of the VAR.

(Insert Table 3)

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[8]. According to Cheung and Lai (1993) the trace test shows more robustness to both skewness and excess kurtosis in the residuals than the maximum eigenvalue test. Further, according to Kasa (1992) the trace test tends to be more powerful than the maximum eigenvalue test when the eigenvalues are evenly distributed.

[9]. According to Dickey et al. (1991) and Johansen and Juselius (1990) the larger the number of nonzero vectors, the more stable is the system. More than one significant vector implies that the economic systems are stationary in more than one direction.

Comparing the results from the pre crisis to the post crisis, it is clear that after the crisis the nominal exchange rates of the Far East against the US dollar shared a long-run stationary relationship between each other with or without the inclusion of the Australian dollar.

Tables 4 and 5 show the Johansen cointegration tests using the exchange rates based on the Japanese yen during the pre and post crisis period, respectively. Once again during both periods, three sets of tests are conducted. During the pre crisis period (table 4), no significant vector(s) are found by both the eigenvalue and the trace tests when only the Far East exchange rates are in the VAR. This result is similar to the one using the US dollar based exchange rates (table 2). Adding the Australian dollar into the VAR does not change the results. In other words, no significant vector(s) are show by both tests. This result is different from the one using the US dollar based exchange rates, where a stationary long-run relationship was found between the exchange rates. Test between just the ASEAN members indicates one significant vector at the 5% level by the maximum eigenvalue test only.[10] This results is also opposite of the one using the US dollar based exchange rates. In summary exchange rates based on the Japanese yen also fail to provide much evidence of cointegration during the pre crisis period, 1990-1997.

(Insert Table 4 here)

Table 5 shows the results from the post crisis period. In all three tests, ample evidence of significant vectors is found. In the first test involving the Far East rates, the trace test shows four significant vectors at 1% level or above. As stated earlier, larger the number of significant vectors the stronger the cointegration results. Four vectors imply at least four possible long run relationships between these exchange rates. Adding the Australian dollar in

[10] This relatively a weak result.

the VAR once again the trace test shows four significant vectors. And testing just between the ASEAN members, three nonzero vectors are indicated by both tests. During the crisis and the periods after, exchange rates based on the Japanese yen are strongly cointegrated. Once again this result is similar to the one obtained using the exchange rates based on the US dollar (table 3).

(Insert Table 5 here)

Looking at the overall cointegration results not much difference is found comparing the results between the yen based and the dollar based tests. The period including and after the crisis provide more evidence of cointegration and this is true using both dollar and yen based exchange rates. Result from the yen based tests seems to show more relationships between the Far East exchange rates. But, this does not ascertain the domination of the yen in the region after the crisis.

3.2 Normalized Equations and Coefficients

The estimated cointegrating vector(s) is given economic meaning by normalizing on the Thailand exchange rate. Normalized equation and coefficients are only provided when a nonzero vector(s) is found. The exchange rate of Thailand is applied to normalize because the baht was the first currency to be affected by the crisis. Technically normalization could have been based on any one of the exchanges rates in the VAR. The implications of the result stayed the same irrelevant of normalization variable. The normalized vectors reflect the interrelationships among these real exchange rates. Normalized coefficients can be interpreted as long run elasticities. The normalized vector(s) are shown in table 6. Using the chi-square test, all variables are tested for significance as indicated by Johansen and Juselius (1990).

(Insert Table 6)

Looking at the relationships between the exchange rates vis-à-vis the yen during the post crisis period only the test including the ASEAN countries indicated a cointegrating vector. All coefficients are significant except the one on Singapore. The influence of the peso of Philippines is inverse but small in absolute size. During the crisis and after, in the ASEAN countries tests (third test) all variables are significant at the 5% level or above, including Singapore. This is the only test where the currency from Singapore is significant in the post crisis period. The coefficients are relatively large in absolute size except for in the case of Philippines peso again. Indonesia and Malaysia now impose an (significant) inverse effect. No comparison is possible between the remaining two tests as during the post crisis period no significant vectors were found. Malaysia, Taiwan, Philippines and Indonesia all influence the Thai exchange rate significantly in all tests. The coefficients on Malaysian exchange rate and Taiwanese exchange rate are large in absolute value in all tests indicating a large size effect. The Australian exchange rate seems to show a significant one to one positive effect (in the second test). Both Malaysian and Taiwanese currencies (in absolute value) seem to impose larger effect than the Australian dollar.

Results based on the US dollar are quite similar to the yen based results. During the pre crisis period the second test with the Australian dollar indicates a cointegrating relationship. Most exchange rates are found to be insignificant except for the Thai, Taiwanese and the Australian currencies. The coefficients on Taiwan and Australia are negative and small in absolute size. During the crisis and after, the result from the US based exchange rates is very similar to the yen based exchange rates described above. Once again currencies from Taiwan, Indonesia and Philippines are significant in all three tests. The Malaysia imposes an insignificant effect in the ASEAN countries test. Comparing between the two periods, the Australian effect is smaller in the post period and the Taiwanese effect is larger in absolute value. A direct comparison of the coefficients between the US dollar based and yen based tests indicate that size of coefficients vary across and it is difficult to ascertain where more coefficients are larger (in absolute value).

3.3 Results of Band Spectrum Regression (BSR)

At the beginning of this decade, numerous researches have been conducted to compare the influence of the Japanese Yen and the US Dollar on the Asian economies. The research hypothesis was that economic links among Asian countries increased rapidly, with Japan at the root of this increase. However, the overall conclusion is that although the Japanese yen gained influence gradually, it is still the US dollar that dominated the region.

The results from cointegration tests based separately on the pre- and post-period strongly suggest an increasingly compact interaction among Asian currencies since the Asian crisis began. Then what's the role of Japanese Yen and US Dollar in this crisis? We re-examine the issue of "Yen Bloc" or "Dollar Bloc" in the region by a new method--band spectral regression (BSR).

The most attractive element of BSR is its ability to discriminate between the long run and the short-term relationship among variables. As a frequency domain technique, it can separate different frequency bands according to the time periods with which our research is concerned. A long run relationship is represented in the low frequency band while a short-term relationship is represented in the high frequency band.

To compare the impact of movements of the dollar and the yen to the system respectively, we conduce the tests on two sets of exchange rates. One is a system of exchange rates based on the US dollar, and the other is a system of exchange rates based on the Japanese yen. Each currency is regressed against the yen or the dollar separately.

One caveat added to the BSR is the question of how to choose the truncation point of the frequency for defining the high frequency band and the low frequency band. Since we have a large daily data sample that span over years, it gives us the freedom of choosing a narrow frequency band to correspond to the term of long run and short-term. We arbitrarily take the $(0, \pi/20)$ as the low frequency band and the other end, $(19\pi/20, \pi)$, as the high frequency band[11], in order to capture the average movements of exchange rates within two days (the

[11] Let w denotes the frequency and *l* denotes the length of the cycle or period. Each frequency is equivalent to a particular periodicity (or a cycle length), i.e. $l=2\pi/w$, $0\leq w\leq\pi$. Thus the frequency $w=\pi/20$ corresponds to a 2 months cycle ($w=2\pi/40$, $l=40$), and the frequency

short-term) and longer than two months (the long run). The results are reported in tables 7 and 8.

(Insert Tables 7 and 8 here)

The results of a system of exchange rates based on the Japanese yen are summarized in table 7. Panel A shows that before the crisis in the long run (low frequency band) the yen significantly influences most currencies except the TWD. However, the impact of the yen is negative rather than positive, which may suggest that the strength and weakness of the yen relative to the US dollar has a great influence on the exchange rates that are related to them. For example, the positive relation between the yen and the three ASEAN countries (Singapore, Malaysia, and Thailand) may reflect Japan's economic influence in these countries, while other countries are more influenced by the US economic power. When the JY is strengthened, the currencies of the three ASEAM countries also strengthened with it, and vice versa. Taiwan has significant economic relations with Japan; however, its currency is pegged to the US dollar. That may be the reason that we observe a negative but nonsignificant relation between the yen and the TWD. Similar pattern is found in our short-term (the high frequency band) test. The highly liquid foreign exchange market exactly reflects the underlying economic forces.

In the post-crisis period, however, the power of the Japanese yen is significantly weakened. In the short-term, only the AUD has significant co-movement with the yen, and even in the long run where one expects that it's the underlying economic forces move the exchange rates, the yen only has significant influence on the SKW, the THB, the TWD and the INDON. The results suggest that after the crisis, not only Japan lose its economic power in the region, the Japanese yen also lose the power as a competitor of the US dollar in the foreign exchange market.

Table 8 confirms our analysis above. The US dollar has significant positive influence on all the currencies in the region both in the short-term and long run. After the crisis, the US dollar only lose its influence slightly on the SKW and the INDON, but for all the rest of the currencies, the dollar still has significant positive influence, both in the short-term and long run.

The overall results lead to the interesting conclusion that before the crisis broke out in July 2, 1997, although Asian currencies significantly follow the US Dollar, the Japanese yen was also a big force in the region. However, after the period of crisis, the Yen Bloc almost disappeared. While Japan loses its economic power in the region, the Japanese yen also lose its power in the foreign exchange market. It is to the US dollar that most Asian currencies are closest.

5. Conclusion

This paper extends the research of money market integration in three dimensions. Firstly, the dynamic interaction and the stochastic time-series properties of a set of East Asian currencies are examined. Secondly, the effect of the East Asian financial crisis on the relationship among exchange rates is examined. The interactions among exchange rates are compared in two sub-periods— the pre-crisis period from January 1, 1990 to July 2, 1997 and the post-crisis period from July 2, 1997 to August 30, 2002. Thirdly, both the time domain technique and the frequency domain technique are initiated for the analysis. The frequency domain technique, which is powerful in unraveling the stable long run and short run relationship, is novel to the literature of money market.

Nine Australian-Asian exchange rates vis-à-vis the Japanese yen and the US dollar are included: the Australian Dollar, the Singapore Dollar, the Malaysian Ringgit, the Thai Baht, the Indonesian Rupiah, the Philippines Peso, the South Korean Won, and the Taiwanese Dollar. Both the yen and the US dollar based rates are applied to check for the dominance of the yen or the dollar in the region and the change in the dominance of these currencies after the Asian crisis.

First, consistent with the literature, significant deviations from normality and the presence of unit roots are documented for each currency. Thus the application of OLS using these exchange rates may not be appropriate without the preliminary diagnostic test on unit roots.

Second, the Johansen multivariate cointegration method is applied to check for potential long-run stationary relationship(s) between the exchange rates in the study. For both the Japanese yen and the US dollar based exchange rates three sets of cointegration tests are conducted. The first test only includes the Far East countries exchange rates in the VAR; in the second test the Australian dollar is added to the VAR and the last test checks for cointegration among the ASEAN member countries. Very little evidence of cointegration is found during the pre crisis period (January 1990 to June 1997) and this is true using both yen and dollar based exchange rates. During and after the crisis period (July 1997 to August 2002) ample evidence of cointegration is found in all three tests. Exchange rates based on the yen indicate more significant relationships than the dollar based rates. Normalized equations based on the significant vectors indicate significant effect of the rates included in the VAR. From these results it is difficult to ascertain the dominance of the yen or the dollar. Results do show that the inclusion of the other currencies in the ASEAN bloc provides a rich pattern of cointegration after the crisis, and the cointegration among ASEAN currencies becomes even stronger. The evidence strongly suggests an increasing interaction among Asian exchange rates after the financial crisis.

Third, the results from Band Spectrum Regression (BSR) showed a significant structure change in the relationship between Asian currencies and the Japanese yen or the US dollar respectively. By separating different frequency bands the BSR made explicit the short run and long run relationships between the exchange rates. The overall results lead to the interesting conclusion that before the crisis breaks out in July1997, although Asian currencies significantly follow the US dollar, but the Japanese yen is also a big force in the region. However, after the period of crisis, the Yen Bloc almost disappeared. While Japan loses its economic power in the region, the Japanese yen also lose its power in the foreign exchange market. It is to the US dollar that most Asian currencies are closest.

Our results can be supported by several economic backgrounds. Firstly, from the early1990's to the beginning of the crisis, the US dollar enjoys a real appreciation. During that period the Asian emerging economies have stable high growth rates, with their currencies pegged to the US dollar, the currencies enjoy the real appreciation also. Thus, during the pre-crisis period, the exchange rate system has long run equilibrium and is closely related to the US dollar. Secondly, the Asian emerging economic has a similar structure, such as export structure and financial system. From the depreciation of the Thai Baht, the competition (export, the ability to attract capital, etc.) in the region became intensive. The real appreciated countries were soon under the attack of speculative pressure and the depreciation was transmitted from one country to another. That may be why the lead-lag relationship among exchange rates during the period of crisis is observed. Thirdly, Japan as the leading economy in the region has met its own economic problem, thus cannot act the role the US had played in the 1994-1995 Mexican crisis. On the contrary, its poor performance exacerbated the fragile economic situation in the region. Thus, what we have found from the BSR is that the exchange rates are more influenced by the US dollar than by the Japanese yen. At the last, the ASEAN bloc has close relationships in both economics and politics. It is not surprising that they are close to each other and formed a main force in the region.

The results have important implications for understanding financial markets integration and the increasingly important role of the currency bloc of Southeast Asian currencies. The findings of a close relationship between the Southeast Asian currencies should be of interest to policymakers, managers, and others interested in Asian financial markets. Results presented in this paper advocate further research in this field.

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Table 1
Basic Statistics

Exchange Rates	Obs	Mean	Variance	Skewness	Kurtosis	J-B
Daily Exchange Rates vis-à-vis the US Dollar						
Pre Crisis Period, January 1990-June 1997						
AUSD	1957	0.2902[a]	0.0028	0.7017[a]	-0.1218	161.788***
SD	1957	0.4535[a]	0.0083	0.2118[a]	-1.1220[a]	117.289***
MR	1957	0.9531[a]	0.0014	0.4568[a]	-1.1581[a]	177.436***
TB	1957	3.2319[a]	0.0002	-0.6308[a]	2.6939[a]	721.535***
INDR	1957	7.6504[a]	0.0069	-0.1439[a]	-0.9647[a]	82.642***
PHP	1957	3.2453[a]	0.0034	-1.1249[a]	1.0523[a]	503.004***
SKW	1957	6.6556[a]	0.0035	-0.0936	-0.0828	3.4154
TWD	1957	3.2752[a]	0.0011	-0.5465[a]	-0.5040[a]	118.112***
Crisis and Post Crisis Period, July 1997-August 2002						
AUSD	1349	0.5200[a]	0.0121	-0.0485	-1.0355[a]	60.796***
SD	1349	0.5375[a]	0.0025	-1.0329[a]	1.4393[a]	356.321***
MR	1349	1.3209[a]	0.0063	-3.0064[a]	11.2879[a]	9186.27***
TB	1349	3.7027[a]	0.0090	-0.4330[a]	1.4895[a]	166.866***
INDR	1349	9.0146[a]	0.1227	-1.8296[a]	3.5440[a]	1458.58***
PHP	1349	3.7658[a]	0.0221	-0.5532[a]	0.1340	69.824***
SKW	1349	7.1090[a]	0.0152	-0.1827[a]	1.6993[a]	169.813***
TWD	1349	3.4833[a]	0.0028	-0.7647[a]	0.4234[a]	141.556***
Daily Exchange Rates vis-à-vis the Japanese Yen						
Pre Crisis Period, January 1990-June 1997						
AUSD	1957	-4.4664[a]	0.0306	-0.0484	-0.8973[a]	66.424***
SD	1957	-4.3032[a]	0.0080	0.4158[a]	-0.6914[a]	95.373***
MR	1957	-3.8036[a]	0.0163	0.1234[b]	-0.7356[a]	49.097***
TB	1957	-1.5248[a]	0.0194	-0.0367	-0.7140[a]	42.013***
INDR	1957	2.8938[a]	0.0468	-0.3517[a]	-0.9306[a]	110.951***
PHP	1957	-1.5114[a]	0.0325	-0.6066[a]	0.0339	120.098***
SKW	1957	1.8990[a]	0.0345	-0.5633[a]	-0.7591[a]	150.478***
TWD	1957	-1.4814[a]	0.0239	-0.0735	-1.1039[a]	101.124***
Crisis and Post Crisis Period, July 1997-August 2002						
AUSD	1349	-4.2630[a]	0.0170	-0.2999[a]	-1.1953[a]	100.531***
SD	1349	-4.2452[a]	0.0082	-0.4028[a]	-0.8191[a]	74.191***
MR	1349	-3.4618[a]	0.0112	-0.8477[a]	1.0728[a]	226.234***
TB	1349	-1.0800[a]	0.0108	-0.4440[a]	-0.3824[a]	52.533***
INDR	1349	4.2319[a]	0.1143	-2.2058[a]	4.2824[a]	2124.76***
PHP	1349	-1.0169[a]	0.0261	-0.6072[a]	-0.6289[a]	105.140***
SKW	1349	2.3263[a]	0.0113	-0.9960[a]	2.8285[a]	672.665***
TWD	1349	-1.2994[a]	0.0043	-0.4621[a]	-0.5753[a]	66.621***

Notes:

a and b imply significantly different from zero at 1% and 5% level, respectively.
J-B = Jarque-Bera normality statistics.
*** implies rejection of null of normality at 1% level.

Table 2

Pre-Crisis Cointegration Tests Results

Exchange Rates vis-à-vis the US Dollar

Test 1: Thailand, Malaysia, Singapore, South Korea, Taiwan, Indonesia and Philippines

Vectors	Maximum Eigenvalue Test	Trace Test	Eigenvalues
r = 0	36.22	115.30	0.0197
r = 1	27.99	79.07	0.0152
r = 2	23.42	51.08	0.0128
r = 3	15.66	27.66	0.0085
r = 4	7.04	12.00	0.0039
r = 5	4.68	4.97	0.0026
r = 6	0.29	0.29	0.0002

Lags = 4

Test 2: Thailand, Malaysia, Singapore, South Korea, Taiwan, Indonesia, Philippines and Australia

Vectors	Maximum Eigenvalue Test	Trace Test	Eigenvalues
r = 0	65.39[a]	164.52[b]	0.0352
r = 1	28.51	99.14	0.0155
r = 2	26.22	70.63	0.0143
r = 3	18.52	44.41	0.0101
r = 4	12.88	25.89	0.0070
r = 5	7.73	13.00	0.0042
r = 6	4.72	5.27	0.0026
r = 7	0.55	0.55	0.0003

Lags = 4

Test 3: Thailand, Malaysia, Singapore, Indonesia and Philippines

Vectors	Maximum Eigenvalue Test	Trace Test	Eigenvalues
r = 0	31.41	61.31	0.0171
r = 1	14.94	29.90	0.0082
r = 2	7.99	14.96	0.0044
r = 3	6.02	6.97	0.0033
r = 4	0.95	0.95	0.0005

Lags = 4

Note:

a & b implies significant vector at the 1% & 5% level, respectively.

Table 3
Post Crisis Cointegration Tests Results
Exchange Rates vis-à-vis the US Dollar

Test 1: Thailand, Malaysia, Singapore, South Korea, Taiwan, Indonesia and Philippines

Vectors	Maximum Eigenvalue Test	Trace Test	Eigenvalues
r = 0	85.05[a]	186.98[a]	0.0561
r = 1	39.12	101.93[b]	0.0262
r = 2	27.42	62.81	0.0185
r = 3	16.40	35.40	0.0111
r = 4	9.69	19.00	0.0066
r = 5	6.52	9.31	0.0044
r = 6	2.79	2.79	0.0019

Lags = 6

Test 2: Thailand, Malaysia, Singapore, South Korea, Taiwan, Indonesia, Philippines and Australia

Vectors	Maximum Eigenvalue Test	Trace Test	Eigenvalues
r = 0	84.49[a]	215.91[a]	0.0557
r = 1	38.11	131.42[b]	0.0255
r = 2	33.07	93.31	0.0222
r = 3	22.01	60.24	0.0148
r = 4	16.98	38.23	0.0115
r = 5	10.76	21.25	0.0073
r = 6	8.14	10.49	0.0055
r = 7	2.35	2.35	0.0016

Lags = 4

Test 3: Thailand, Malaysia, Singapore, Indonesia and Philippines

Vectors	Maximum Eigenvalue Test	Trace Test	Eigenvalues
r = 0	38.71[b]	90.34[a]	0.0259
r = 1	23.62	51.63[b]	0.0159
r = 2	15.00	28.02	0.0101
r = 3	10.63	13.02	0.0072
r = 4	2.39	2.39	0.0016

Lags = 4

Note:

a & b implies significant vector at the 1% & 5% level, respectively.

Table 4

Pre-Crisis Cointegration Tests Results

Exchange Rates vis-à-vis the Japanese Yen

Test 1: Thailand, Malaysia, Singapore, South Korea, Taiwan, Indonesia and Philippines

Vectors	Maximum Eigenvalue Test	Trace Test	Eigenvalues
r = 0	43.05	122.66	0.0233
r = 1	27.82	79.61	0.0151
r = 2	24.24	51.78	0.0132
r = 3	12.65	27.54	0.0069
r = 4	9.38	14.90	0.0051
r = 5	4.77	5.51	0.0026
r = 6	0.75	0.75	0.0004

Lags = 4

Test 2: Thailand, Malaysia, Singapore, South Korea, Taiwan, Indonesia, Philippines and Australia

Vectors	Maximum Eigenvalue Test	Trace Test	Eigenvalues
r = 0	50.52	155.25	0.0273
r = 1	30.81	104.73	0.0167
r = 2	25.43	73.93	0.0138
r = 3	21.70	48.50	0.0118
r = 4	11.86	26.80	0.0065
r = 5	9.65	14.95	0.0053
r = 6	4.94	5.30	0.0027
r = 7	0.36	0.36	0.0002

Lags = 4

Test 3: Thailand, Malaysia, Singapore, Indonesia and Philippines

Vectors	Maximum Eigenvalue Test	Trace Test	Eigenvalues
r = 0	37.69[b]	66.61	0.0205
r = 1	18.28	28.92	0.0100
r = 2	7.53	10.64	0.0041
r = 3	2.80	3.11	0.0015
r = 4	0.31	0.31	0.0002

Lags = 4

<u>Note</u>:

b implies significant vector at the 5% level.

Table 5
Post-Crisis Cointegration Tests Results
Exchange Rates vis-à-vis the Japanese Yen

Test 1: Thailand, Malaysia, Singapore, South Korea, Taiwan, Indonesia and Philippines

Vectors	Maximum Eigenvalue Test	Trace Test	Eigenvalues
r = 0	44.57	169.93[a]	0.0326
r = 1	40.49	125.35[a]	0.0297
r = 2	32.29	84.86[a]	0.0237
r = 3	25.39	52.57[a]	0.0187
r = 4	17.23	27.18	0.0127
r = 5	6.66	9.95	0.0049
r = 6	3.28	3.28	0.0024

Lags = 4

Test 2: Thailand, Malaysia, Singapore, South Korea, Taiwan, Indonesia, Philippines and Australia

Vectors	Maximum Eigenvalue Test	Trace Test	Eigenvalues
r = 0	51.70[b]	206.59[a]	0.0377
r = 1	43.39	154.89[a]	0.0317
r = 2	37.64	111.51[a]	0.0276
r = 3	27.23	73.87[b]	0.0200
r = 4	22.62	46.64	0.0167
r = 5	16.07	24.01	0.0119
r = 6	5.05	7.94	0.0037
r = 7	2.89	2.89	0.0021

Lags = 4

Test 3: Thailand, Malaysia, Singapore, Indonesia and Philippines

Vectors	Maximum Eigenvalue Test	Trace Test	Eigenvalues
r = 0	38.63[b]	99.91[a]	0.0283
r = 1	28.91[b]	61.28[a]	0.0213
r = 2	23.40[b]	32.37[b]	0.0172
r = 3	6.09	8.98	0.0045
r = 4	2.89	2.89	0.0021

Lags = 4

Note:

a & b implies significant vector at the 1% & 5% level, respectively.

Table 6

Normalized Equations and Elasticities

Exchange Rates vis-à-vis the Japanese Yen

Thailand	Malaysia	Singapore	S Korea	Taiwan	Indonesia	Philippines	Australia
Pre-Crisis Results							
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
1.00** (4.58)	0.102** (10.95)	0.403 (0.65)	-	-	0.502** (5.85)	-0.058** (8.27)	-
Post Crisis Results							
1.00** (23.28)	0.458** (19.38)	0.283 (8.49)	0.347 (9.00)	-1.039** (16.75)	-0.217** (19.12)	0.664** (23.40)	-
1.00** (18.91)	1.341** (20.18)	-0.508 (2.31)	0.501** (10.02)	-1.961** (12.80)	-0.343** (23.08)	0.211** (11.42)	1.068
1.00** (19.56)	-3.349** (22.70)	4.187** (20.72)	-	-	-0.474** (21.64)	-0.020** (20.98)	-

Exchange Rates vis-à-vis the US Dollar

Thailand	Malaysia	Singapore	S Korea	Taiwan	Indonesia	Philippines	Australia
Pre-Crisis Results							
-	-	-	-	-	-	-	-
1.00** (6.20)	-0.016 (0.09)	0.448 (1.85)	-0.011 (0.01)	-0.082** (4.75)	0.461 (1.62)	-0.017 (0.46)	-0.105** (10.09)
-	-	-	-	-	-	-	-
Post Crisis Results							
1.00** (13.78)	0.796** (13.37)	-0.757 (3.42)	0.708 (0.94)	-0.379** (7.56)	-0.264** (37.05)	0.829** (11.57)	-
1.00** (9.78)	1.083** (14.47)	-0.103 (0.07)	0.950** (6.37)	-1.329** (4.97)	-0.254** (19.72)	-0.006** (30.73)	0.925** (32.69)
1.00** (6.79)	1.545 (4.49)	-3.513** (9.03)	-	-	-0.420** (6.59)	1.747** (11.57)	-

Note:

Chi-square statistics in the parentheses. ** imply significant at the 5% level.

Table 7

Band Spectrum Regression Results

Japanese Yen

Panel A: Pre-crisis period (January 1, 1990 – June 30, 1997)				
Dep.v.—Ind.v	Low frequency (Band interval: 0, $\pi/20$)		High frequency (Band interval: $19\pi/20, \pi$)	
	$\hat{b}$	*t*-value	$\hat{b}$	*t*-value
JY-AUD	-0.959	-3.645**	-0.158	-0.827
JY-MYR	2.401	7.743**	1.481	4.549**
JY-SGD	1.323	14.021**	0.708	6.366**
JY-SKW	-1.220	-5.706**	-0.723	-6.625**
JY-THB	8.305	10.169**	-1.039	-3.070**
JY-TWD	-0.393	-0.878	-0.206	-1.716
JY-PHILP	-1.027	-4.539**	-0.638	-5.214**
JY-INDON	-1.259	-10.022**	-0.681	-6.929**
Panel B: Post-crisis Period (July 1, 1997 - August 30, 2002)				
JY-AUD	0.106	1.132	0.279	2.853**
JY-MYR	0.186	1.547	0.042	0.529
JY-SGD	0.332	1.718	0.152	0.974
JY-SKW	0.299	4.381**	-0.079	-1.238
JY-THB	0.272	2.775**	0.044	0.886
JY-TWD	0.930	6.088**	0.295	1.859
JY-PHILP	0.076	1.120	0.056	1.075
JY-INDON	0.066	2.439*	0.021	0.931

Note:

1. In each regression the JY is the dependent variable with other currencies as the independent variable.
2. The *t*-test statistic test the null hypothesis of $\hat{b}=0$.
3. ** Significant at 1% level
   * Significant at 5% level

Table 8

Band Spectrum Regression Results
US Dollar

Panel A: Pre-crisis period (January 1, 1990 – June 30, 1997)				
Dep.v.—Ind.v	Low frequency (Band interval: 0, $\pi/20$)		High frequency (Band interval: $19\pi/20, \pi$)	
	$\hat{b}$	*t*-value	$\hat{b}$	*t*-value
USD-AUD	0.813	32.543**	0.761	19.367**
USD-MYR	1.125	40.704**	1.044	33.482**
USD-SGD	1.330	13.418**	0.771	8.887**
USD-SKW	0.762	33.443**	0.581	21.944**
USD-THB	1.062	155.860**	0.867	38.920**
USD-TWD	0.936	45.211**	0.575	13.680**
USD-PHILP	0.763	29.612**	0.603	20.349**
USD-INDON	1.259	10.022**	0.681	6.929**
Panel B: Crisis Period (July 1, 1997- August 30, 2002)				
USD-AUD	0.346	5.069**	0.381	4.553**
USD-MYR	0.499	6.687**	0.288	4.883**
USD-SGD	0.767	11.698**	0.643	9.712**
USD-SKW	0.094	1.086	0.253	5.682**
USD-THB	0.375	4.378**	0.116	2.521*
USD-TWD	0.946	9.195**	0.675	9.361**
USD-PHILP	0.199	3.357**	0.123	2.516*
USD-INDON	-0.066	-2.439*	-0.021	-0.931

Note:

4. In each regression the USD is the dependent variable with other currencies as the independent variable.
5. The *t*-test statistic test the null hypothesis of $\hat{b}=0$.
6. ** Significant at 1% level
   * Significant at 5% level