UCD GEARY INSTITUTE
DISCUSSION PAPER SERIES

Assessing Co-ordinated Asian Exchange Rate Regimes

Raj Aggarwal[∀] and Cal B. Muckley[♣]

August 2008

JEL Classifications: F33, F31, F42, F02
Keywords: Exchange Rate Regimes, Asia, Currency Pegs, Basket Exchange Rates

[∀] College of Business Administration, University of Akron, Akron, OH 44325.

[♣] Banking and Finance Group, S-314, Smurfit Business School, University College Dublin, Ireland. E-mail: cal.muckley@ucd.ie; Tel: 00-353-1-8322167; corresponding author.

Assessing Co-ordinated Asian Exchange Rate Regimes

Raj Aggarwal[∀] and Cal B. Muckley[♣]

August 2008

JEL Classifications: F33, F31, F42, F02
Keywords: Exchange Rate Regimes, Asia, Currency Pegs, Basket Exchange Rates

[∀] College of Business Administration, University of Akron, Akron, OH 44325.

[♣] Banking and Finance Group, S-314, Smurfit Business School, University College Dublin, Ireland. E-mail: cal.muckley@ucd.ie; Tel: 00-353-1-8322167; corresponding author.

Assessing Co-ordinated Asian Exchange Rate Regimes

Abstract

This study assesses alternative Asian exchange rate regimes and finds short- and long-run currency dynamics more conducive to the possibility of introducing a common peg based on a basket of the European euro, the United States dollar and the Japanese yen than the alternative of re-introducing a United States dollar peg exchange rate regime. Exchange rate systems of 3- 4- and 5- Asian currencies are examined and the dynamics in a set of 4 European currencies prior to the introduction of the Euro provides benchmark evidence. The evidence for an Asian basket peg regime is strengthened when, unlike in prior studies, the long-run parameters are estimated while accounting for generalised autoregressive conditional heteroscedasticity effects.

1. Introduction

There is ongoing debate regarding the merits and disadvantages of fixed versus flexible exchange rates. While flexible exchange rates allow greater macroeconomic policy freedom, fixed exchange rates facilitate the economic integration between countries with such exchange rates. Should the Asian monetary authorities introduce a more co-ordinated exchange rate regime? Given the high levels of foreign exchange reserves in the region, it is certainly possible for monetary authorities to impose at least a reasonable coordinated exchange rate regime. Pegging to a basket of currencies reduces exchange rate volatility and India has long pegged its exchange rate to an unannounced currency basket and China moved to a similar regime with a different basket of currencies on July 21, 2005. Further, using a common basket of currencies as an exchange rate peg means that changes in exchange rates outside the common region would have no effects on intra-regional exchange rates.

However, is it feasible to adopt a common basket peg exchange rate regime in Asia? Or should the regional monetary authorities revert to an exchange rate regime focused exclusively on keying to the United States dollar or to separate currency baskets? The extant literature examines relevant macroeconomic criteria, *e.g.,* the level of correlation of economic shocks and the level of intra-regional trade (see Mundell 1961 and McKinnon 1963), advocating the inception of a more co-ordinated Asian exchange rate regime as a tentative step towards an optimal currency area (see Eichengreen and Bayoumi 1996, Ling 2001 and Huang and Guo 2006). This study examines the feasibility of adopting a common currency basket as a peg for exchange rates in Asia based on the statistical time series properties of a set of Asian exchange rates and comparing them to the time series properties of a benchmark set of European exchange rates prior to the introduction of the Euro.

It is found in this study that the current Asian experience, in terms of the time series properties of exchange rates, is comparable to that in Europe in the run-up to European Monetary Union[1]. Overall, while it appears desirable to introduce a more co-ordinated Asian exchange rate regime, the precise nature of this regime remains an unresolved issue.

2. Possible Asian Exchange Rate Regimes

Several ideas have been proposed with respect to the choice of the nature of an interim more co-ordinated Asian exchange rate regime. This study examines two specific regimes. *First*, is the possibility of a currency basket system in Asia (see Ogawa and Ito 2002, Kawai 2002, Williamson 1999, 2005). *Second*, is the reversion to the United States dollar standard in Asia (see McKinnon 2000 and McKinnon and Schnabl 2004).

Virtually all of the Asian authorities seemed to have traditionally followed a United States dollar standard at some point in the past (see Frankel and Wei 1994, McKinnon and Schnabl 2004 and Kearney and Muckley 2007a, 2007b). However, contemporary Asian trade and investment linkages seem to have gradually eroded the significant merit of that system with respect to price stability, financial market and trade integration, and current account imbalances, culminating (in part) in the Asian financial crisis of 1997-98 (see Ito, Ogawa and Sasaki 1998, Kwan 2001 and McKinnon and Schnabl 2003). In particular, the weaknesses of the United States dollar standard were exacerbated by rising Asian trade and investment linkages, both intra-regionally and, in an absolute sense, with Japan, alongside a volatile United States dollar to Japanese yen exchange rate in the three year period prior to the 1997 crisis. Indeed, a reversion to the dollar standard would imply that undesirable fluctuations in effective trade weighted exchange rates are likely to remain, unless the exchange rates of important trading partners are stabilised relative to one another.

In contrast, the basket peg alternative allows a link between a country's national currency and a basket of important trading partner currencies, while allowing some flexibility within a particular range. Flexibility in exchange rates also has the virtue of allowing greater flexibility in setting domestic monetary policies and so it is worthwhile emphasising that we do not envisage a rigid peg exchange rate system but rather a crawling peg or a basket peg

[1] That said, however, as was the case in Europe prior to the common currency, so far it appears there may be insufficient regional political solidarity necessary to support a co-ordinated regional exchange rate regime in Asia. Nonetheless, while the assessment of political integration is beyond the scope of this paper, there is an underlying institutional framework in Asia which is gradually extending its collective remit to further co-ordinate regional financial and monetary arrangements (see Rana 2002).

with wide margins is proposed as an attractive solution. As we show in this study, this eventuality would assure a relatively stable trade-weighted exchange rate.

Following the macroeconomic findings from the optimal currency area literature concerning the inception of a more co-ordinated exchange rate regime and the arguments with respect to the common basket peg and the United States dollar peg regimes, it appears that a central challenge facing the introduction of a more co-ordinated exchange rate regime in Asia is the internal transient and long-run dynamics of the various regional exchange rates. In summary, it seems significantly less costly to introduce a more co-ordinated exchange rate regime if regional exchange rates are compatible with the proposed exchange rate system. By compatibility, we mean that the rates' time series dynamics satisfy five simple and intuitive statistical criteria to a similar extent that these criteria were satisfied by a set of European exchange rates prior to the inception of the European Monetary Union.

Against this background, we make three contributions to the extant literature. *First*, given that the US, Japan, and the Euro area are the largest trading partners of the selected Asian countries (see Williamson 2005), we calibrate the feasibility of introducing a common basket peg exchange rate regime oriented about these three currencies, the Euro, the Japanese yen and the United States dollar, relative to an exchange rate system focusing exclusively on the United States dollar. This calibration is with respect to short- and long-run time series properties in the eight-year-period since the Asian financial crisis. Therefore, unlike previous studies, our focus is on the behaviour of exchange rates rather than their determinants (see Frankel 1993, Frankel and Wei 1994 and Bowman 2005). *Second*, in the spirit of Eichengreen and Bayoumi (1996), the Asian exchange rate time series properties are compared and contrasted with those of select European exchange rates in the eight-year-period prior to the 1 January 1999 establishment of European Monetary Union. *Third*, a further novelty of our study is that it accounts for generalised ARCH (henceforth GARCH) when estimating long run time series properties in the exchange rate levels. This phenomenon is suspected to have compromised the power of tests utilised in earlier articles (see Aggarwal and Mougoue 1993, 1996 and Tse and Ng 1997).

3. The Data, the Methodology and the Econometric Models

The data consists of daily (close of business) bilateral United States dollar and basket currency exchange rates for the Indonesian rupiah, the Korean wan, the Philippine peso, the Taiwan dollar and the Thailand baht over the period 1 January 1999 through to 29 December

2006. It also comprises, by way of a benchmark, a set of European currencies: the Belgian franc, the Dutch guilder, the French franc and the German mark expressed in terms of the ECU over the period 1 January 1991 through to 30 December 1998. All data is sourced from *Datastream International Ltd.*

This set of select Asian currencies is chosen on the basis of two criteria. *First*, the economies concerned have been long-standing members of the Association of Southeast Asian Nations and are signatories of the Chiang-Mai initiative.[2] Hence, they are committed to regional financial and economic integration. Moreover, Huang and Guo (2006) conclude that the Indonesian rupiah, the Korean won and the Thailand baht are of especial relevance to any future Asian currency zone. *Second*, these currencies exhibit pronounced unilateral European euro and Japanese yen effects as well as United States dollar effects (see Bowman 2005). The Chinese yuan, the Hong Kong dollar the Malaysian ringgit, and to a lesser extent the Singapore dollar values are almost entirely determined by changes in the United States dollar and hence including these rates in a study of the time series properties of a set of exchange rates relative to the US dollar would give misleading results and not make sense.

The set of select European currencies acts as a reasonable benchmark case as its components were the only currencies actively complicit in the process to European currency market integration since the 1970s and the set is sufficiently small to lend itself to examination with the statistical models used in this article. The behaviour of these currencies, during the period examined, is of especial relevance as they have, since 1 January 1999, irrevocably linked their currencies to the Euro.

Concerning the basket peg exchange rate regime, this article considers that basket peg eventuality comprised of an equally weighted linear combination of the European euro, the Japanese yen and the United States dollar (see Ogawa and Ito 2002 and Williamson 2005).[3] The United States dollar represents an important trading partner for most Asian countries and should clearly be included in any basket for an exchange rate peg (see Williamson 2005). The argument in support of the Japanese yen, as an incremental currency of choice, is compelling. *First*, Japan is the largest and most important regional economy with respect to trade (see Kearney and Muckley 2005 and Huang and Guo 2006) and of central importance with respect to foreign direct investment (see Urata 2001). *Second*, growing unilateral Japanese yen effects on many of the region's currencies are well established, *i.e.*, unilateral basket pegs are

[2] Except Taiwan, which is not internationally recognised as a separate political entity from mainland China even though it is a distinct currency area and it actively seeks to demonstrate its political independence.
[3] In this paper we do not estimate optimal weights in a currency basket, leaving that for future research.

apparent in the region (see Aggarwal and Mougoue 1996, Hernandez and Montiel 2003, Bowman 2005 and Huang and Guo 2007). *Finally*, researchers at the Bank of Japan and the Japanese Ministry of Finance have also expressed an interest in pursuing this possibility (see Kamada and Takagawa 2005). The hypothesis that the notional basket peg should also include the European euro is also cogent for a different set of reasons.[4] *First*, the euro zone, alongside the United States dollar and the Japanese yen, is in the top three extra-regional trading partners of all the Asian economies concerned (see Williamson 2005). *Second*, while euro zone currency effects in Asia are generally of secondary importance after those of the Japanese yen and the United States dollar such effects are documented (see Kearney and Muckley (2007a, 2007b)). A common peg is considered superior to unilateral pegging as it insulates regional trade dynamics from outside disturbances[5], yields an environment conducive to enhanced regional monetary integration, and facilitates the availability of a forward market against, *e.g.*, the United States dollar, for the participating currencies.

Five simple and intuitive statistical criteria for the successful inception of a basket peg exchange rate regime and a United States dollar exchange rate regime are considered, *i.e.*, the alternative exchange rate regimes are examined by altering the numeraire currency from the basket peg currency to the United States dollar. A European exchange rate set, in terms of the ECU (European Currency Unit), is also examined by way of a benchmark. Specifically, these criteria relate to *first* stability, *second* pair-wise and multivariate correlations, *third*, the correlations' persistence, *fourth* volatility transmission, and *fifth* long-run equilibrium time-series relations in the select aforementioned sets of exchange rates and exchange rate returns expressed in terms of appropriate numeraire currencies.

The greater the stability of the Asian currency sets in terms of the basket currency and the United States dollar and the European currency, the more important is the corresponding numeraire currency in relation to innovations in the Asian or European currency sets. Notwithstanding instability in the currency sets, the larger the pair-wise and multivariate Asian and European rate return correlations and the more pronounced the correlations' persistence, the greater the likelihood that this set of currencies might be managed in a more co-ordinated fashion, relative to the select numeraire currency. With the same motivation in mind, periods of relative tranquillity and periods of relative volatility should ideally not

[4] The Euro is a free floating currency and is not managed relative to Asian currencies.
[5] Williamson (2005) indicates that a common basket peg regime, in the East Asia region, outperforms unilateral country baskets in stabilizing effective exchange rates, during 2000-04. This is tantamount to stabilizing the relative price of traded goods or output in respect to the fluctuation in important global currencies. Unilateral exchange rate pegs imply different yen and dollar weights in the currency baskets which may still cause competitive imbalances.

coincide across the Asian and European rate returns. Independent time varying volatilities within a candidate bloc are tantamount to an intrinsic dissatisfaction with the requirement of large correlations between the exchange rate returns. A long-run relationship between the Asian rates and the Japanese yen relative to the United States dollar and the basket currency, or between the European currencies and the ECU, is indicative of the presence of a long-run equilibrium. The greater the extent to which these natural criteria are exhibited in the data, the greater the feasibility of the corresponding exchange rate regime.

The internal long run dynamics of systems of Asian exchange rates are well documented (see Aggarwal and Mougoue 1993, 1996 and Tse and Ng 1997). Taken together, these articles reveal long run relations among sets of Asian currencies with the Japanese yen playing a significant and rising role. These findings are interpreted as indicative of the potential emergence of a Japanese yen dominated regional exchange rate system. However, these articles neglect to consider the impact of ARCH (autoregressive conditional heteroscedasticity) effects on the estimated long run relations. Given the relatively small sample sizes examined this is an unreasonable assumption and hence inference may be misleading (see Hoglund and Ostermark (2003)). In this article, we address this shortcoming by simultaneously accounting for generalised ARCH effects when estimating the cointegration vectors while also providing updated estimates of these long-run relations since the Asian financial crisis.

Groupings of 3-, 4- and 5-currencies are selected by means of an eigenvalue decomposition on each of the standardised variance/covariance matrices of all sets of 3- and 4- Swiss franc exchange rate returns. A Swiss franc exchange rate numeriare is selected as it is a significant and free floating currency. The larger the first eigenvalue of each matrix relative to the summation of the matrix's eigenvalues, the more collinear the variables summarised in that matrix. The groupings are selected with a view to maximising the collinearity criterion. The same methodology is adopted on a moving window of 250-observations to inspect the evolution of the correlations in the various exchange rate systems examined. The persistence of the correlations, in each of the exchange rate systems, is estimated using an orthogonal factor generalised ARCH model (see Alexander 2002). The magnitude of the volatility transmission in the various exchange rate systems is estimated using a multivariate BEKK specified GARCH model (see Engle and Kroner 1995). The number of long run relations tying the system of exchange rates together is estimated using a variation on the Johansen (1988) econometric methodology. This variation is motivated by the literature in the area of cointegration testing, in the context of ARCH effects.

The literature in the area of cointegration testing, in the context of ARCH effects, is in its infancy. The theoretical literature (see Lee and Tse 1996, Silvapulle and Podivinsky 2000 and Hoglund and Ostermark 2003) indicates that ARCH effects aggrandise the size of the Johansen 1988 cointegration test. For example, Lee and Tse 1996 indicate that while the Johansen 1988 cointegration test tends to overreject the null hypothesis of no cointegration in favour of finding cointegration, the problem is generally not very serious. Silvapulle and Podivinsky 2000 report similar results. In contrast, Hoglund and Ostermark 2003 conclude that the eigenvalues of the long run information matrix for the Johansen 1988 cointegration test are highly sensitive to conditional heteroskedasticity and that therefore this multivariate statistic is only reliable in the context of homoskedastic processes. This latter finding, regarding the size of the cointegration test, becomes increasingly pronounced the more integrated the ARCH process considered. That said, these contributions pertain to low dimensional systems and, as a result, are of limited empirical relevance. For example, empirical contributions (see Alexakis and Apergis 1996, Gannon 1996 and Pan *et al.* 1999), across a wider range of system dimensions, tend to indicate that these ARCH effects and their variants exert a significant and deleterious impact on the statistical test's power properties. Specifically, the aforementioned empirical literature identifies significant gains in statistical power once ARCH effects are controlled, when testing for cointegration, using the Johansen 1988 technique.

In the light of the preceding discussion a modified Johansen testing procedure is estimated with a view to mitigating for the deleterious implications of ARCH effects on the estimation of the rank of the long run information matrix in the specified vector error correction model (henceforth VECM). Specifically, following Gannon (1996), we adopt a modified test for common roots in which we account for GARCH effects in the correlating combinations of residuals. Consider the p-dimensional VECM:

$$\Delta x_t = \pi x_{t-1} + \Sigma_{i=1}^{k-1} \pi_i \Delta x_{t-1} + \varepsilon_t \qquad (1)$$

$$\pi = \Sigma_{i=1}^{k} \pi_i - I \qquad (2)$$

$$\pi_i = -\Sigma_{i+1}^{k} \pi_j, (i = 1,..., k-1) \qquad (3)$$

The residuals, ε_t, are assumed independent normally distributed p-dimensional with mean zero and variance, Ω. The parameters $(\pi, \pi_1,..., \pi_{k-1}, \Omega)$ are unrestricted and are estimated by maximum likelihood estimation. The x_t are vectors of series containing the exchange rates. Now, consider two auxiliary equations:

$$\Delta x_t = \Sigma_{i=1}^{k-1} b_{1i} \Delta x_{t-1} + r_{0t} \quad (4)$$

$$x_{t-1} = \Sigma_{i=1}^{k-1} b_{2i} \Delta x_{t-1} + r_{1t} \quad (5)$$

where b_1 and b_2 are estimated by ordinary least squares (see Johansen and Juselius, 1990). The vectors of series r_{ot} and r_{1t} contain the residuals from the auxiliary regressions. Note that the VECM, *Eq.* (1) can now be reformulated as a two-stage estimation process:

$$r_{0t} = \alpha\beta' r_{1t} + error \quad (6)$$

The null hypothesis, H_0, that the components of x_t are cointegrated may be stated as

$$H_0 : \pi = \alpha\beta' \quad (7)$$

This implies that q = rank (π) < p. The rows of the (p*q) matrix β' are the distinct cointegrating vectors of x_t *i.e.*, $\beta'(x_t)$ are *I*(0). The elements of α represent the loadings of each of the *r* cointegrating relations.

The canonical correlations can be estimated from the stacked residuals via *Eq.* 6 where the weights, $\omega_{1i}...\omega_{pi}$ and $\kappa_{1i}...\kappa_{pi}$ are canonical weights

$$\hat{j}_i = \hat{\omega}_{1i} r_{01i} + ... + \hat{\omega}_{pi} r_{0pi} \quad (8)$$

and

$$\hat{z}_i = \hat{\kappa}_{1i} r_{11i} + ... + \hat{\kappa}_{pi} r_{1pi} \quad (9)$$

Where *r* refers to the residuals from *Equations* (4) and (5) and the subscript *i* refers to the i^{th} pair of canonical variates. Therefore these variates $\hat{j}_i$ and $\hat{z}_i$ have a zero mean.

Finally, estimate GARCH (1,1) equations for $\hat{j}_i$ and $\hat{z}_i$ for *i=1, … ,q*.

$$\hat{j}_{it} = \rho_i \hat{z}_{it} + u_{it} \quad (10)$$

$$h_{it} = Var(\hat{j}_{it} / \hat{z}_{it}) = \alpha_{i0} + \alpha_{i1} u_{t-1}^2 + \beta_{i1} h_{t-1} \quad (11)$$

and compare the t-statistic for ρ with the tabulated values of the statistic given in Mackinnon (1991). Hence, an estimate of each eigenvalue, λ_i, is available $\rho_i \approx \sqrt{\lambda_i}$. Neglecting GARCH effects gives inefficient estimates of the $\lambda_i s$ while allowing for GARCH effects partially accounts for simultaneous volatility effects in the system. If there is common volatility across the series entering the system then linear combinations of the deviations from long-run paths will capture these common factors.

The concern is that in neglecting to account for common volatility shocks, the test statistics may fail to reveal significant common roots. The test statistics are estimated from the procedure described in equations 8, 9, 10 and 11. We perform the two-stage procedure with and without accounting for GARCH effects. The variates are constructed using canonical coefficients as weights. This procedure provides an estimate, robust to GARCH effects, of the number of cointegrating vectors.

4. Estimation Results

To investigate the possibility that a more co-ordinated Asian exchange rate regime might be initiated and, in particular, to investigate the relative merits of specific more co-ordinated exchange rate regimes, *i.e.,* a basket peg exchange rate regime and the United States dollar peg exchange rate regime, this article examines groupings of 3- and 4-currencies which exhibit the highest level of multilateral correlation alongside the full 5-currency set. Correlations are estimated with currencies expressed in terms of a relatively independent currency, the Swiss Franc. This range of dimensions of currency sets is examined *firstly* as a small grouping of eligible currencies is more likely to be politically feasible. *Secondly* over-specification, of the adopted VECM, may otherwise have harmful consequences for the sizes and powers of the statistical tests performed in the examination of the fifth criterion, *i.e.* the long-run relations criterion. In particular, critical values may be too large due to the inclusion of an irrelevant variable (see Gannon 1996). This may imply spurious empirical results.

The select 3-currency set contains the Korean won, the Philippine peso and the Taiwan dollar while the 4-currency set extends the latter set to include the Thailand Baht and the 5-currency set extends to include the Indonesian rupiah. These sets of currencies are extended to include the Japanese yen when the United States dollar exchange rate regime is considered with respect to the criterion of a long-run equilibrium.

Table 1 reports summary test statistics. The augmented Dickey-Fuller estimates indicate that these currency returns appear to be stationary while the currency exchange rates are probably integrated of order one, *I(1)*. This finding statistically motivates the adoption of short- and long-run modelling techniques to examine the outlined criteria. The variances of the exchange rate return series, in terms of the United States dollar and the benchmark currency are comparable while the European currency unit exchange rate returns exhibit a markedly low level of variance. This reflects the co-ordinated exchange rate system in Europe in the run-up to the Euro, relative to the regime in Asia, since the 1997-98 financial crises. According to a Lagrange Multiplier test, significant ARCH effects are prevalent. This finding motivates a modified test for cointegration to assess the behaviour of long-run relations in the data, with respect to the fifth criterion. Naturally, it also motivates this article's examination of volatility transmission with-in the currency groupings. Finally, while there is evidence of skewness, there is markedly more evidence of excess kurtosis in the unconditional return distributions. We therefore follow Bollerslev (1987) in utilising a student t distribution for the exchange rate innovations in our various GARCH models.

[Please insert Table 1 about here]

Table 2 presents the correlation matrices for the Asian currencies, the Japanese yen, and the Euro in terms of the United States dollar and the Asian currencies, excluding Japan, in terms of the basket currency. Also, the correlation matrix for the European currency returns in terms of the European Currency Unit (henceforth ECU) is presented. It appears, from a consideration of the arithmetic mean correlations, that the correlation matrices of the Asian currencies denominated in terms of the basket currency and the European currencies in terms of the ECU are of a similar magnitude, while the United States dollar denominated exchange rate set exhibits relatively low arithmetic mean correlations. While these preliminary findings reflect the relative importance of the United States dollar in exchange rate determination in Asia, they also reveal the scope for an alternative Asian exchange rate regime as a result of the comparison with the behaviour of a set of European currencies in the run up to EMU.

[Please insert Table 2 about here]

Figure 1 portrays the levels and returns of the select sets of Asian exchange rates and the Japanese yen in terms of the United States dollar and the select set of Asian currencies in terms of the basket currency and it also portrays the European currency set in terms of the ECU. Figure 2 portrays the bivariate and multivariate correlations in the same sets of exchange rate returns. The Asian exchange rates are rebased to 100 on 1 January 1999 and the European rates are rebased to 100 on 1 January 1991. The Indonesian rupiah, the Korean won and the Philippine peso are relatively unstable when expressed in terms of either numeraire. Taken together, the Asian currencies, exhibit significantly less stability than the European currencies. The European currencies range to approximately ten percent from the initial rate while the Asian currencies expressed in terms of either numeraire are substantially more unstable, they are displaced in excess of thirty percent from the initial rate. This is also demonstrated in clear terms by inspection of the volatility in the returns series. Hence, from the view point of the first criterion, stability, the basket peg and United States dollar regimes provide comparable results, while both regimes appear less promising than did the Euro in the run up to European Monetary Union. Turning now to the correlations, which are computed on a moving 250-day window. The heavy lines in Panels A and B represent the 3-, 4- and 5- currency groupings multivariate correlations. In both instances, the line representing the highest correlation corresponds with the 3-currency set and the multivariate correlation declines with increases in the size of the currency grouping. In Panel C the heavy line represents the multivariate correlation in the full 4-currency grouping. The mean multivariate United States dollar correlations vary between 0.3 and 0.5, while the mean multivariate basket currency correlations vary between 0.5 and 0.9. In contrast, the mean multivariate ECU returns' correlations vary between 0.4 and 0.8 and then following a generally upward trend, particularly in the latter period.

[Please insert Figures 1 and 2 about here]

Table 3 indicates that statistically significant t-distributed GARCH coefficients are estimated on the first and second principal components across the sets of exchange rate returns considered. Therefore, these t-distributed GARCH (1,1) models indicate that the correlations vary in a persistent manner rather than erratically (see Alexander 2002).

[Please insert Table 3 about here]

Taken together, the results presented so far suggest that the United States dollar multivariate correlations are generally lower than those of the basket currency, which are similar in magnitude to those of the ECU return multivariate correlations. Also, all sets of exchange rate returns exhibit significant persistence and thus comparable results regarding the third criterion. These results indicate the superiority of the basket peg exchange rate regime relative to the United States dollar peg exchange rate regime with respect to the second criterion and the similarity of the performance of both regimes with respect to the third criterion.

Table 3 also presents results concerning volatility transmission from a t-distributed BEKK specification for the multivariate GARCH (1,1) model. This specification parsimoniously imposes no cross equation restrictions while ensuring a positive definite conditional variance matrix. While it permits the examination of both the direction and the magnitude of volatility transmission we focus exclusively on a summary measure of the magnitude of volatility transmission. This measurement shows that for the US dollar and basket currency exchange rate sets, generally the larger the set of exchange rates examined the larger is the magnitude of the volatility transmission. Moreover, it is clear that the volatility transmission in the European currency exchange rate set is significantly more pronounced than in the Asian currency exchange rate sets. That said, the basket currency exchange rate sets exhibits considerably more volatility transmission than the US dollar exchange rate sets. As a result, the superiority of the basket peg exchange rate regime relative to the United States dollar exchange rate regime once again appears evident with respect to the fourth criterion.

As indicated by the results presented in Table 1, there is the possibility of cointegration among our exchange rates. Table 4 presents the results from the Johansen (1988) maximum likelihood procedure, a classic set of likelihood ratio 'trace' tests, to estimate the rank of the long run information matrix, *i.e.*, the existence of long run equilibrium relations driving the long run movements. Panels A and B present results concerning the select currency sets and the Japanese yen in terms of the United States dollar and the select currency sets in terms of the basket currency respectively. Panel C presents results concerning the European exchange rates. Following Richards (1995), the order of the associated VECM is selected using the Bayesian Information criterion.

[Please insert Table 4 about here]

Previous research that included the Hong Kong dollar, adopting this statistical test for long run equilibria, reported the existence of a long run relationship (see Aggarwal and Mougue 1996 and Tse and Ng 1997). However, this prior research may have provided spurious results as the Hong Kong dollar was largely determined by the United States dollar during the corresponding time periods (see Kearney and Muckley, 2007a, 2007b). Nonetheless, our article tentatively corroborates those findings by revealing evidence indicative of the existence of a single cointegration vector, at the 10 percent significance level, in the United States dollar denominated currency systems examined. It also suggests an absence of cointegration relations when the exchange rate systems are expressed in terms of the basket currency. In contrast, compelling evidence of a single cointegration relation is estimated in the European currency data set.

Overall, the findings so far appear to indicate that the United States dollar exchange rate peg regime is superior to the basket peg exchange rate regime with respect to the fifth criterion, although the evidence is fairly tentative. Notwithstanding this, however, Table 1 presents pervasive significant ARCH effects. It is possible that these effects have reduced the power of the Johansen (1988) test procedure, hence providing spurious results.

In Table 5 the results of a modified test for common roots, in which generalised ARCH effects in the correlating combinations of residuals are accounted for, is presented for the aforementioned exchange rate systems. The European currencies exhibit 2 cointegrating vectors. The modified test reveals strengthened evidence of cointegration throughout the United States dollar numeraire Asian exchange rate sets and it finds significant evidence of cointegration throughout the basket peg numeraire Asian exchange rate sets. Therefore, the modified test reveals starkly different evidence relative to the classic Johansen (1998) 'trace' test. It indicates that all of the exchange rate sets exhibit cointegration. As a result, the fifth criterion appears to be satisfied with respect to both the prospective United States dollar exchange rate regime and the basket peg exchange rate regime.

[Please insert Table 5 about here]

5. Conclusions

In this study, we have examined several time series properties since the Asian financial crisis of 1997-98 for Asian currencies which have demonstrated marked unilateral European euro and Japanese yen effects, alongside important United States dollar effects. These time series properties were selected with a view to assessing the compatibility of sets of currencies to more co-ordinated exchange rate regimes in light of recent macroeconomic findings indicating the potential of the aforementioned regimes. Specifically, a 3-currency set was examined which contained the Korean won, the Philippine peso and the Taiwan dollar while a 4-currency set extended the latter set to include the Thailand Baht. Our 5-currency set extended the 4-currency set to include the Indonesian rupiah. These currency sets were considered in terms of the United States dollar and a basket currency, *i.e.*, a linear combination of the European euro, the Japanese yen and the United States dollar. Comparative time-series properties of a set of benchmark European currencies, expressed in terms of the European Currency Unit, comprising the Belgian franc, the Dutch Guilder, the French Franc, and the German mark, were also considered.

The behaviour of these exchange rate sets was examined with reference to five intuitive time series criteria (*i.e.* stability, correlations, persistence of correlations, volatility transmission, and long-run relations). In particular the candidate exchange rate regimes of introducing a basket peg or a United States dollar peg in the Asia region were examined. The set of European currencies acted as a useful benchmark, as these rates, since January 1 1999, have been successful member currencies of the European Monetary Union.

This study documents that short- and long-run currency dynamics are more conducive to the possibility of introducing a common peg for Asian currencies based on a basket of the European euro, the United States dollar and the Japanese yen compared to the alternative of re-introducing a United States dollar peg exchange rate regime. Specifically, the benchmark set of European currencies, as expected, performs well on the 5 criteria while the Asian basket peg regime also performs well across the outlined criteria, with the exception of the criterion of stability. In contrast, the United States dollar exchange rate regime performs well only on the criteria of the persistence of correlations and long-run relations. Notably, the evidence for a common Asian basket peg regime is strengthened when the long-run parameters are estimated while accounting for generalised autoregressive conditional heteroscedasticity effects. In summary, this study documents that currency dynamics in Asia are conducive to the possibility of introducing a common peg for Asian currencies based on a basket of the European euro, the United States dollar and the Japanese yen and such an arrangement is better than the alternative of re-introducing a United States dollar peg exchange rate regime. These findings clearly have important policy implications for scholars and policy-makers interested in Asian countries.

References

Aggarwal, R., Mougoue, M., 1993. Cointegration among Southeast Asian and Japanese currencies: Preliminary evidence of a yen bloc? Economics Letters 41, 161-166.

Aggarwal, R., Mougoue, M., 1996. Co-integration among Asian currencies: evidence of the increasing influence of the Japanese yen. Japan and the World Economy 8, 291-308.

Alexander, C., 2002. Principal component models for Generating Large GARCH Covariance matrices, Economic Notes: Review of Banking, Finance and Monetary Economics 31, 337-359.

Alexakis, P., Apergis, N., 1996. ARCH effects and cointegration: Is the foreign exchange market efficient? Journal of Banking and Finance 20, 687-697.

Bollerslev, T., 1987. A conditionally heteroskedastic time series model for speculative prices and rates of return. Review of Economics and Statistics 69, 542-547.

Bowman, C., 2005. Yen block or Koala block? Currency relationships after the East Asian crisis. Japan and the World Economy 17, 83-96.

Eichengreen, B., Bayoumi, T., 1996. Is Asia an Optimum Currency Area? Can It Become One? Regional, Global and Historical Perspectives on Asian Monetary Relations. Center for International and Development Economics Research. Paper C96-081.

Engle, R.F., Kroner K., 1995. Multivariate Simultaneous Generalized ARCH. Econometric Theory 11, 122-150.

Frankel, J.A., 1993. Is Japan Creating a Yen Bloc in East Asia and the Pacific? In: Frankel, J., Kahler, M., (Eds.). University of Chicago Press, Chicago, Regionalism and Rivalry: Japan and the U.S. in Pacific Asia, 53-85.

Frankel, J.A., Wei S., 1994. Yen block or dollar block? Exchange rate policies of the East Asian economies. In Ito, T., Krueger A.O., (Eds). University of Chicago Press, Macroeconomic linkages: savings, exchange rates and capital flows, Chicago, 295-329.

Gannon, G., 1996. First and second order inefficiency in Australasian currency markets. Pacific-Basin Finance Journal 4, 315-327.

Hernandez, L., Montiel, P., 2003. Post-crisis exchange rate policy in five Asian countries: filling in the hollow middle? Journal of the Japanese and International Economies 17(3), 336-369.

Hoglund, R., Ostermark R., 2003. Size and power of some cointegration tests under structural breaks and heteroskedastic noise. Statistical Papers 44, 1-22.

Huang, Y., Guo F., 2006. Is currency union a feasible option in East Asia? A multivariate structural VAR approach. Research in International Business and Finance 20, 77-94.

Huang, Y., Guo, F., 2007. Effects of East Asian Financial Integration: Is There a Japanese Dominance? Review of Pacific Basin Financial Markets and Policies 20 (No. 2, June), 193-214.

Ito, T., Ogawa, E., and Sasaki Y., 1998. How Did the Dollar Peg Fail in Asia? Journal of the Japanese and International Economies 12, 256-304.

Johansen, S., 1988. Statistical Analysis of Cointegrating Vectors. Journal of Economic Dynamics and Control 12, 231-254.

Johansen, S., Juselius K., 1990. Maximum Likelihood Estimation and inference on cointegration – with applications to the demand for money. Oxford Bulletin of Economics and Statistics 52, 169-210.

Kamada K., Takagawa, I., 2005, Policy Coordination in East Asia and across the Pacific. Springer-Verlag.

Kawai, M., 2002. Exchange Rate Arrangements in East Asia: Lessons from the 1997-98 Currency Crisis, Bank of Japan Monetary and Economic Studies 20, 167-214.

Kearney, C., Muckley, C., 2005. The Role of the Yen in Asian Exchange Rate Determination. In: Batten J., Fetherston, T., (Eds.). Asian Pacific Financial Markets in Comparative Perspective, Contemporary Studies in Economics and Financial Analysis, Elsevier Science, 87.

Kearney, C., Muckley, C., 2007a. Is there a Yen Block emerging in North and Southeast Asia? International Journal of Finance and Economics 12, 337-351.

Kearney, C., Muckley, C., 2007b. Reassessing the evidence of an emerging yen block in North and Southeast Asia. International Review of Economics and Finance 16, 255-271.

Kwan C.H., 2001. Yen Block: Toward Economic Integration in Asia. Brookings Institution Press.

Ling, H.Y.P., 2001. Optimum Currency Area in East Asia. A Structural VAR Approach. ASEAN Economic Bulletin 18, No. 2.

Mantalos, P., 2005. ECM-Cointegration test with GARCH (1,1) Errors. Interstat. Online at http://interstat.stat.vt.edu/InterStat/.

MacKinnon, J. G., 1991. Critical values for cointegration tests. In R.F. Engle & C.W. J. Granger (Eds.), Modelling Long Run Economic Relationships (pp. 267-276). Oxford: Oxford University Press.

McKinnon, R.I., 1963. Optimum Currency Areas. American Economic Review 53, 717-725.

McKinnon, R.I., 2000. The East Asian dollar standard, life after death, World Bank Workshop on Rethinking the Easy Asian Miracle. Economic Notes 29, No.1.

McKinnon, R.I., Schnabl G. 2003. Synchronised Business Cycles in East Asia and Fluctuations in the Yen-Dollar Exchange Rate. World Economy. 26, 1067-89.

McKinnon, R.I., Schnabl G. 2004. The Return to Soft Dollar Pegging in East Asia: Mitigating Conflicted Virtue. International Finance 7(2), 169-201.

Mundell, R., 1961. A Theory of Optimum Currency Areas. American Economic Review 51, 657-665.

Lee, T.H., Tse. Y., 1996. Cointegration tests with conditional heteroskedasticity. Journal of Econometrics 73, 401-410.

Ogawa, E., Ito T., 2002. On the Desirability of a Regional Basket Currency Arrangement. Journal of the Japanese and International Economies. 16(3), 317-334.

Osterwald-Lenum, M., 1992. A note with quantiles of the asymptotic distribution of the maximum likelihood cointegration rank test statistics. Oxford Bulletin of Economic Statistics. 54, 461-471.

Rana, P.B., 2002. Monetary and financial cooperation in East Asia: The Chiang Mai Initiative and Beyond. Asian Development Bank, Economics and Research Department Working Paper Series no 6 (February).

Richards A.J., 1995. Co-movements in National Stock Market Returns: Evidence of Predictability, but not Cointegration. Journal of Monetary Economics 36, 631–654.

Seo, B. 2004. Asymptotic Distribution of the Cointegrating Vector Estimator in Error Correction Models with Conditional Heteroskedasticity. No. 463 North American Winter Meetings, Econometric Society.

Tse, Y.K., Ng L.K., 1997. The Cointegration of Asian Currencies Revisited, Japan and the World Economy, 9, 109-114.

Urata, S., 2001. Emergence of an FDI-Trade Nexus and Economic Growth in East Asia. In: Stiglitz J., Yusuf, S., (Eds.), Rethinking the East Asian Miracle, Washington DC: World Bank and Oxford University Press.

Williamson, J., 1999. The case for a Common Basket Peg for East Asian Currencies. In: Collignon, S., Pisani-Ferry J., Park, Y.C., Exchange Rate Policies in Emerging Asian Countries. London: Routledge.

Williamson, J., 2005. A Currency Basket for East Asia, Not Just China, Policy Briefs in International Economics, no.PB05-1, Institute for International Economics.

Table 1: Summary Statistics

Currency	Variance	Skewness	Exc. Kurtosis	ARCH	Unit Root
United States dollar					
IR	1.11	-0.24[a]	12.87[a]	41.82[a]	-40.13[a] [-2.17]
KW	0.16	-0.04	3.66[a]	119.99[a]	-38.13[a] [-0.64]
PP	0.22	-5.57[a]	136.48[a]	65.78[a]	-43.78[a] [-1.79]
TD	0.09	0.33[a]	35.27[a]	335.59[a]	-36.12[a][-1.28]
TB	0.16	0.14	15.70[a]	130.18[a]	-47.55[a] [-2.06]
JY	0.39	0.00	2.57[a]	3.64[c]	-44.61[a] [-1.99]
Asian Basket rates					
IR	0.98	0.16[a]	11.84[a]	66.72[a]	-28.44[a] [-2.17]
KW	0.17	0.17[a]	1.09[a]	29.62[a]	-40.62[a] [-1.43]
PP	0.19	1.53[a]	25.22[a]	102.69[a]	-26.01[a] [-1.34]
TD	0.13	-0.02	2.26[a]	82.38[a]	-50.89[a][-0.65]
TB	0.18	-0.19[a]	4.79[a]	12.11[a]	-46.75[a] [-1.77]
European Currency Units					
BF	0.03	-1.16[a]	21.51[a]	364.55[a]	-26.75[a] [-1.64]
DG	0.03	-1.61[a]	48.56[a]	363.87[a]	-35.84[a] [-1.62]
FF	0.05	-1.47[a]	23.96[a]	136.87[a]	-42.07[a] [-1.77]
GM	0.03	-1.86[a]	26.46[a]	137.43[a]	-34.67[a] [-1.56]

Notes. The Table contains summary statistics concerning the Asian continuously compounded currency returns denominated in the United States dollar and the Basket currency and four European currency returns expressed in European Currency Units (ECUs). Currency exchange rates are represented: basket currency = an equally weighted linear combination of the European euro, the Japanese yen and the United States dollar, BF = Belgian Franc, DG = Dutch Guilder, ECU = European Currency Unit, FF = French Franc, GM = German Mark, IR = Indonesian Rupiah, JY = Japanese Yen, KW = Korean Won, PP = Philippines Peso, TD = Taiwan Dollar, TB = Thailand Baht and the USD = United States dollar. The returns expressed in the United States dollar and the Asian Basket rates are examined from 1 January 1999 through to 29 December 2006. The returns expressed in ECUs are examined from 1 January 1991 through to 30 December 1998. For example, IR, under the sub-heading 'United States dollar' represents the Indonesian rupiah-United States dollar continuously compounded exchange rate return. A Lagrange multiplier test is performed with respect to first-order ARCH. The unit root summary statistic is the Augmented Dickey Fuller test statistic; in square brackets find the test statistic for the difference of the corresponding currency. The lag length is determined by minimising the Bayesian Information Criterion. The superscripts a, b and c indicate significance at the 1%, 5% and 10% levels, respectively

Table 2: Currency Correlations

United States Dollar

	IR	KW	PP	TD	TB	JY	EURO
IR	1.00	-0.03	0.03	0.11	0.28	0.10	0.02
KW	-0.03	1.00	0.19	0.06	-0.06	0.03	-0.01
PP	0.03	0.19	1.00	0.05	0.01	0.01	0.02
TD	0.11	0.06	0.05	1.00	0.17	0.14	0.10
TB	0.28	-0.06	0.01	0.17	1.00	0.28	0.14
JY	0.10	0.03	0.01	0.14	0.28	1.00	0.30
EURO	0.02	-0.01	0.02	0.10	0.14	0.30	1.00
mean	0.08	0.03	0.05	0.10	0.14	0.14	0.09

Basket Currency

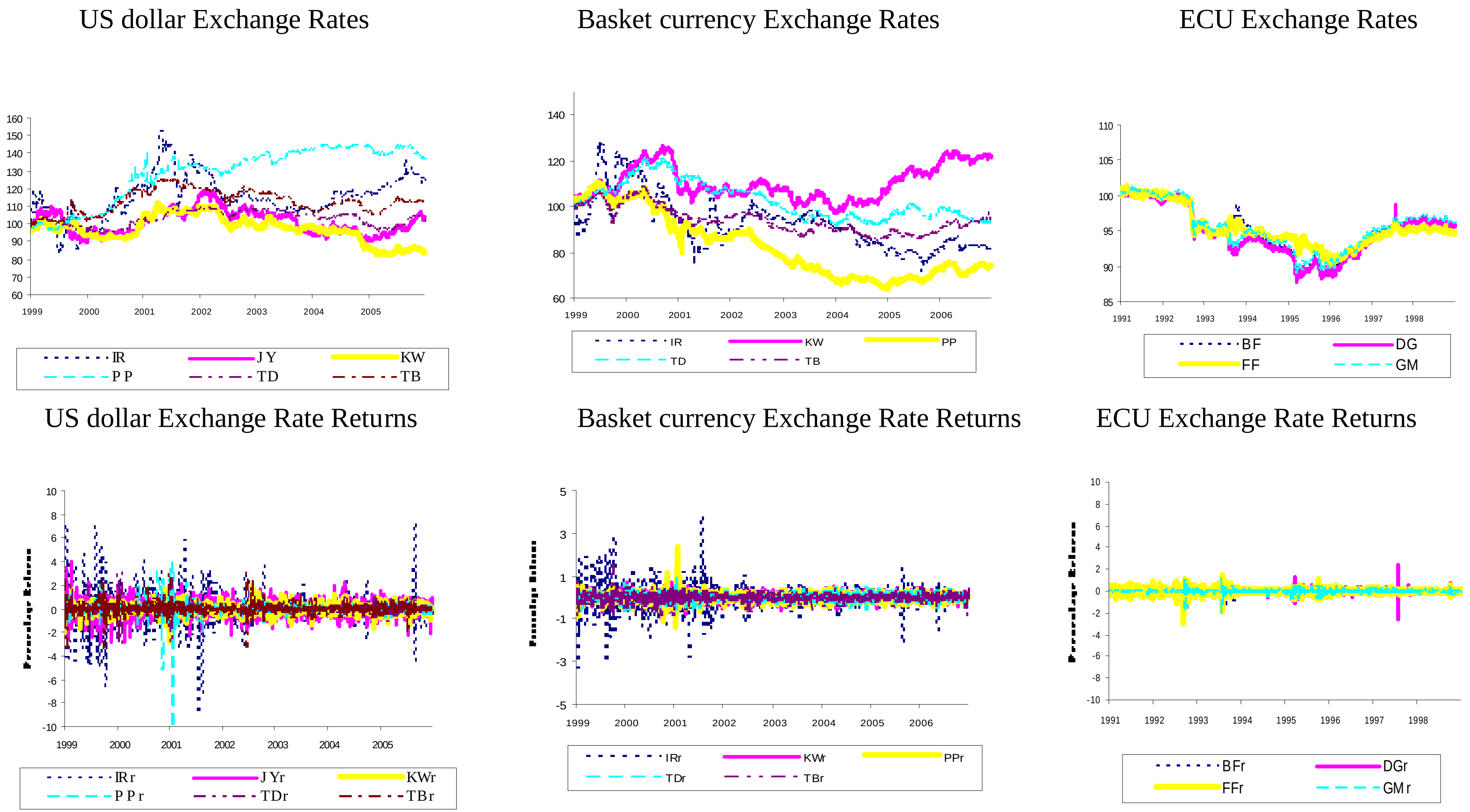
	IR	KW	PP	TD	TB
IR	1.00	0.28	0.31	0.30	0.42
KW	0.28	1.00	0.59	0.70	0.52
PP	0.31	0.59	1.00	0.58	0.51
TD	0.30	0.70	0.58	1.00	0.52
TB	0.42	0.52	0.51	0.52	1.00
mean	0.33	0.52	0.50	0.53	0.49

European Currency Unit

	FF	DG	BF	GM
FF	1.00	0.17	0.22	0.18
DG	0.17	1.00	0.59	0.77
BF	0.22	0.59	1.00	0.58
GM	0.18	0.77	0.58	1.00
mean	0.19	0.51	0.46	0.51

Notes. The Table contains summary correlation matrices with respect to the Asian and Euro currency returns denominated in terms of the United States dollar and the Asian regional currencies in terms of the basket currency and four European currency returns expressed in ECUs. Continuously compounded currency exchange rate returns are represented as CC, Country Currency. For example, IR, under the sub-heading 'United States dollar' represents the Indonesian rupiah-United States dollar continuously compounded exchange rate return. The returns expressed in the United States dollar and the Asian Basket rates are examined from 1 January 1999 through to 29 December 2006. The returns expressed in ECUs are examined from 1 January 1991 through to 30 December 1998. Currency exchange rates are represented: Basket currency = an equally weighted linear combination of the European Euro, the Japanese yen and the United States dollar, BF = Belgian Franc, DG = Dutch Guilder, ECU = European Currency Unit, Euro = European Euro, FF = French Franc, GM = German Mark, IR = Indonesian Rupiah, JY = Japanese Yen, KW = Korean Won, PP = Philippines Peso, TD = Taiwan Dollar and the TB = Thailand Baht.

Figure 1: US dollar, Basket currency and European Currency Unit Exchange Rates and Returns



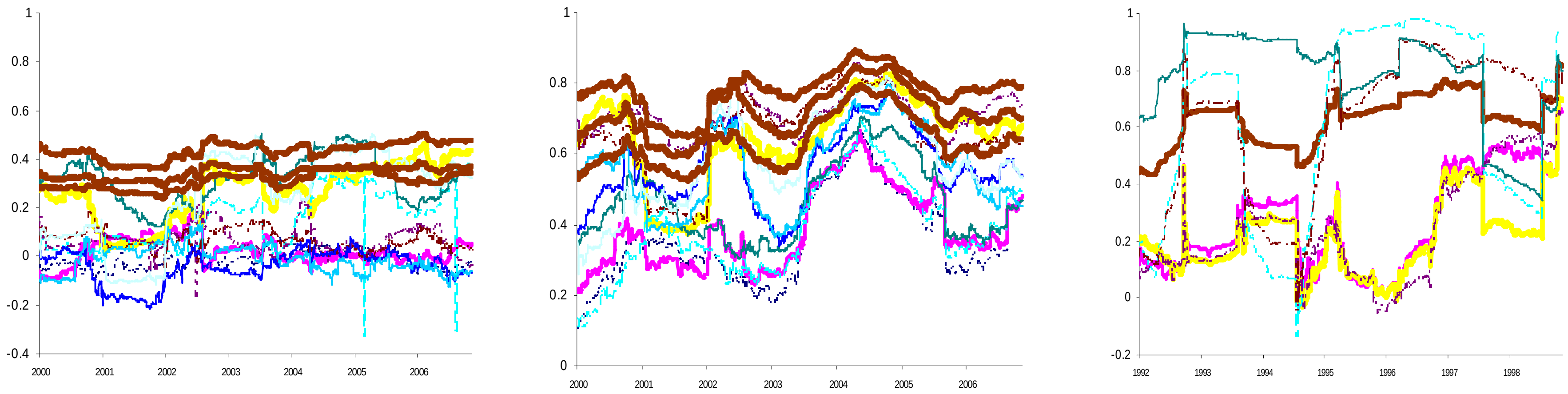
Notes. The Figure contains graphics corresponding to Asian US dollar exchange rates and exchange rate returns and Asian basket currency exchange rates and exchange rate returns over the period 1 January 1999 through to 29 December 2006 and European Currency Unit exchange rates and exchange rate returns over the period 1 January 1991 through to 30 December 1998. The Basket currency is an equally weighted linear combination of the European euro, the United States dollar and the Japanese yen. The terms 'IR', 'JY', ‘KW’, ‘PP’, ‘TD’ and ‘TB’ correspond to the Indonesian rupiah, the Korean won, the Philippine peso, the Taiwan dollar and the Thailand Baht exchange rates, respectively. The terms ‘BF, ‘DG’, ‘FF’ and ‘GM’ correspond to the Belgian Franc, Dutch Guilder, French Franc and German Mark European Currency Unit exchange rates, respectively. These terms followed by an ‘r’ indicate continuously compounded percentage exchange rate returns. The numeraire currency is stated in the Figure sub-title.

Figure 2: Bivariate and Multivariate Currency Return Correlations

Panel A: United States dollar

Panel B: Basket

Panel C: European Currency Unit



Notes. The Figure comprises 3 Panels: A, B and C. The Panels contain bivariate and multivariate correlations estimated in a moving 250 observation window, *i.e.*, an approximate 1-year window, from 1 January 1999 through to 30 December 2006 for the US dollar returns and the basket currency returns and from 1 January 1991 through to 30 December 1998 for the ECU returns. The basket currency is an equally weighted linear combination of the European euro, the Japanese yen and the United States dollar. The window moves by including the incremental observation and dropping the initial observation for each estimation period. In Panel A, the heavy lines represent the 3-, 4- and 5-currency sets of US dollar returns: namely, a 3-currency set containing the Korean won, the Philippine peso and the Taiwan dollar; a 4-currency set that extends the latter set to include the Thailand Baht and a 5-currency set that extends the 4-currency set to include the Indonesian rupiah. The remaining lines represent the time-varying pair-wise correlations between the US dollar currency returns from the 5-currency set. In Panel B the same currency groupings are expressed in terms of the basket currency and the heavy lines represent the aforesaid 3-, 4- and 5-currency sets. The heavy line in Panel C represents the multivariate correlation in the 4-currrency set containing the Belgian franc, the Dutch guilder, the French franc and the German mark in terms of the ECU. The remaining lines, in Panel C, represent the time-varying pair-wise correlations between the ECU currency returns from the 4-currency set.

Table 3: Persistence of Correlations and Volatility Transmission

Panel A: *Persistent Correlations*	*Asian Currencies [United States dollar numeraire]*						*European Currencies*	
	3-currency		4-currency		5-currency		4-currency	
	PC1	PC2	PC1	PC2	PC1	PC2	PC1	PC2
Eigenvalue	1.22	0.97	1.22	1.16	1.39	1.21	2.38	0.92
Cumulative R^2	0.41	0.73	0.31	0.60	0.28	0.52	0.60	0.83
Alpha	0.04[b]	0.01[a]	0.14[a]	0.05[b]	0.02[a]	0.03[b]	0.02[a]	0.00
Beta	0.11[a]	0.13[a]	0.29[a]	0.16[a]	0.05[a]	0.08[a]	0.12[a]	0.12[a]
Delta	0.76[a]	0.75[a]	0.62[a]	0.82[a]	0.88[a]	0.82[a]	0.88[a]	0.89[a]

	Asian Currencies [Basket Currency numeraire]					
	3-currency		4-currency		5-currency	
	PC1	PC2	PC1	PC2	PC1	PC2
Eigenvalue	1.97	0.52	2.71	0.53	2.93	0.84
Cumulative R^2	0.66	0.83	0.68	0.81	0.59	0.75
Alpha	0.02	0.03[a]	0.02	0.02[a]	0.02[b]	0.00[a]
Beta	0.02[a]	0.15[a]	0.02[a]	0.13[a]	0.02[a]	0.05[a]
Delta	0.96[a]	0.57[a]	0.97[a]	0.83[a]	0.97[a]	0.88[a]

Panel B: Volatility Transmission	Asian Currencies [United States dollar numeraire]						*European Currencies*	
	3-currency		4-currency		5-currency		4-currency	
	coeff.	*t-stat.*	*coeff.*	*t-stat.*	*coeff.*	*t-stat.*	*coeff.*	*t-stat.*
	4.26	421.43	3.34	5.82	10.30	159.24	62.24	311.20

	Asian Currencies [Basket Currency numeraire]					
	3-currency		4-currency		5-currency	
	coeff.	*t-stat.*	*coeff.*	*t-stat.*	*coeff.*	*t-stat.*
	3.43	1374.80	9.71	6347.71	17.06	836.03

Notes. The Table contains 2 Panels A and B. Panel A contains T-distributed GARCH (1, 1) conditional volatility coefficients for the first two principal components of seven sets of exchange rate returns: a 3-currency set containing the Korean won, the Philippine peso and the Taiwan dollar; a 4-currency set that extends the latter set to include the Thailand Baht and a 5-currency set that extends the 4-currency set to include the Indonesian rupiah. Results for these three sets of currencies are presented twice: once with the currencies expressed in terms of United States dollars and once with the currencies expressed in terms of the basket currency, *i.e.*, an equally weighted linear combination of the European euro, the Japanese yen and the United States dollar. There is also a 4-currency set of European exchange rates comprising the Belgian Franc, the Dutch Guilder, the French Franc and the German mark. This latter set is expressed in terms of ECUs, European Currency Units. The principal components are represented: PC1 = 1st Principal Component and PC2 = 2nd Principal Component. All exchange rate returns are expressed as continuously compounded returns. The model specification is a vector error correction model (see Johansen, 1988). The superscripts a, b and c indicate significance at the 1 percent, 5 percent and 10 percent levels, respectively. Panel B contains parameter estimates and T-statistics with respect to volatility transmission for the aforesaid seven sets of exchange rate returns. The volatility transmission term is obtained from a BEKK specified T-distributed multivariate GARCH model. The presented coefficient is the summation of the absolute values of the volatility transmission parameters and the associated T-statistic is computed with a standard error obtained using the delta method.

Table 4: Johansen multivariate test for Cointegration

Panel A: US dollar rates	Trace	Critical values 10%	5%	1%
i: 4-currency set				
G = 0	41.88	49.65	53.12	60.16
G <= 1	17.71	32.00	34.91	41.07
G <= 2	6.65	17.85	19.96	24.6
G <= 3	1.31	7.52	9.24	12.95
ii: 5-currency set				
G = 0	87.33[a]	71.86	76.07	84.45
G <= 1	49.73	49.65	53.12	60.16
G <= 2	20.78	32.00	34.91	41.07
G <= 3	7.6	17.85	19.96	24.60
iii: 6-currency set				
G = 0	120.38[a]	97.87	103.68	110.15
G <= 1	75.47	71.81	76.81	83.74
G <= 2	45.58	49.95	53.95	56.73
G <= 3	24.4	31.93	34.07	37.78

Panel B: Basket rates	Trace	Critical values 10%	5%	1%
i: 3-currency set				
G = 0	19.68	32.00	34.91	41.07
G <= 1	9.76	17.85	19.96	24.60
G <= 2	2.29	7.52	9.24	12.95
ii: 4-currency set				
G = 0	23.70	49.65	53.12	60.16
G <= 1	12.16	32.00	34.91	41.07
G <= 2	2.49	17.85	19.96	24.60
G <= 3	0.04	7.52	9.24	12.95
iii: 5-currency set				
G = 0	40.25	71.86	76.07	84.45
G <= 1	20.90	49.65	53.12	60.16
G <= 2	9.62	32.00	34.91	41.07
G <= 3	3.26	17.85	19.96	24.60

Panel C: ECU rates	Trace	Critical values 10%	5%	1%
iv: 4-currency set				
G = 0	298.21[a]	49.65	53.12	60.16
G <= 1	43.44[a]	32.00	34.91	41.07
G <= 2	15.16	17.85	19.96	24.60

Notes. The Table comprises 3 Panels. Panels A and B contain three sets 'i' 'ii' and 'iii' of US dollar and basket currency rates, respectively, and Panel C contains a set 'iv' of ECU rates. In Panel A the terms 'i', 'ii' and 'iii' refer to a 4-currency set containing the Japanese yen, the Korean won, the Philippine peso and the Taiwan dollar; a 5-currency set that extends the latter to include the Thailand Baht and a 6-currency set that extends the 5-currency set to include the Indonesian rupiah. In Panel B the terms 'i', 'ii' and 'iii' refer to a 3-currency set containing the Korean won, the Philippine peso and the Taiwan dollar; a 4-currency set that extends the latter set to include the Thailand Baht and a 5-currency set that extends the 4-currency set to include the Indonesian rupiah. Exchange rate sets 'i' through 'iii' are observed from January 1 1999 through December 30 2006. In Panel C the 4-currency set 'iv', contains the Belgian Franc, the Dutch Guilder, the French Franc and the German mark in terms of the ECU from 1 January 1991 through to 30 December 1998. The model specification estimated is a vector error correction model which is selected with respect to a Bayesian Information Criterion which was observed over vector autoregressive models with lag lengths1 through 5. This criterion indicates that one lag of returns is included in the estimated vector autoregressive model. Gamma 'G' is the number of cointegrating vectors under the null hypothesis. The critical values are simulated or sourced on Table 0 in Osterwald-Lenum (1992). The superscripts a, b and c indicate statistical significance at the 1 percent, 5 percent and 10 percent levels, respectively.

Table 5: Modified multivariate test for Cointegration with GARCH effects

Panel A: US dollar rates	OLS Coeff.	GARCH Coeff.	T-statistic	Critical values 10%	5%	1%
i: 4-currency set						
rho=1	0.09	0.12	-2.69	-3.81	-4.1	-4.65
rho=2	0.06	0.07	-3.62[c]	-3.45	-3.75	-4.29
ii: 5-currency set						
rho=1	0.12	0.07	-4.45[b]	-4.13	-4.42	-4.96
rho=2	0.10	0.09	-5.96[a]	-3.81	-4.1	-4.65
rho=3	0.09	0.05	-3.36	-3.45	-3.75	-4.29
iii: 6-currency set						
rho=1	0.14	0.10	-5.49[a]	-4.42	-4.7	-5.24
rho=2	0.11	0.09	-5.73[a]	-4.13	-4.42	-4.96
rho=3	0.10	0.07	-4.66[a]	-3.81	-4.1	-4.65
rho=4	0.09	0.05	-3.64	-3.45	-3.75	-4.29

Panel B: Basket rates	OLS Coeff.	GARCH Coeff.	T-statistic	Critical values 10%	5%	1%
i: 3-currency set						
rho=1	0.07	0.07	-3.67[c]	-3.45	-3.75	-4.30
rho=2	0.05	0.03	-1.65	-3.05	-3.34	-3.90
ii: 4-currency set						
rho=1	0.10	0.04	-2.96	-3.81	-4.1	-4.65
rho=2	0.07	0.07	-3.80[b]	-3.45	-3.75	-4.29
rho=3	0.05	0.02	-1.43	-3.04	-3.34	-3.90
iii: 5-currency set						
rho=1	0.10	0.04	-2.64	-4.13	-4.42	-4.96
rho=2	0.09	0.08	-4.82[a]	-3.81	-4.10	-4.65
rho=3	0.08	0.07	-3.49[c]	-3.45	-3.75	-4.29
rho=4	0.04	0.03	-1.50	-3.04	-3.3377	-3.90

Panel C: ECU rates	OLS Coeff.	Garch Coeff.	T-statistic	Critical values 10%	5%	1%
iv: 4-currency set						
rho=1	0.22	0.09	-7.11[a]	-3.81	-4.1	-4.65
rho=2	0.07	0.04	-3.37	-3.45	-3.75	-4.29
rho=3	0.03	0.09	-4.22[a]	-3.04	-3.34	-3.90

Notes. The Table comprises 3 Panels. Panels A and B contain three sets 'i' 'ii' and 'iii' of US dollar and Basket currency rates, respectively, and Panel C contains a set 'i' of ECU rates. In Panel A the terms 'i', 'ii' and 'iii' refer to a 4-currency set containing the Japanese yen, the Korean won, the Philippine peso and the Taiwan dollar; a 5-currency set that extends the latter to include the Thailand Baht and a 6-currency set that extends the latter to include the Indonesian rupiah. In Panel B the terms 'i', 'ii' and 'iii' refer to a 3-currency set containing the Korean won, the Philippine peso and the Taiwan dollar; a 4-currency set that extends the latter set to include the Thailand Baht and a 5-currency set that extends the 4-currency set to include the Indonesian rupiah. Exchange rate sets 'i' through 'iii' are observed from January 1 1999 through December 30 2006. The 4-currency set 'iv', presented in Panel B, contains the Belgian Franc, the Dutch Guilder, the French Franc and the German mark expressed in terms of the ECU from 1 January 1991 through to 30 December 1998. Coefficients for rho = 1 ... 4 are the estimated square roots of the eigenvalues, while accounting for t-distributed GARCH effects, of the Johansen long-run information matrix. The coefficients are estimated by Equation 10. The T-statistic critical values are sourced on Table 1 in MacKinnon (1991). The superscripts a, b and c indicate statistical significance at the 1 percent, 5 percent and 10 percent levels, respectively.