RESEARCH ARTICLE

Long-Run Linkages of ASEAN+3 Floating Currencies

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Abstract: The extent with which currencies of the expanded ASEAN grouping commonly known as the ASEAN+3 have attained long-run currency linkages—an important requisite for an eventual monetary integration—is the main focus of this study. High-frequency interbank call rates (nominal exchange rate vis-à-vis the US dollar) data on seven floating currencies of the region with sufficient historical time series covering the period of 1998 to 2012 (weekly: January 7, 1998, to December 26, 2012—average of bid and ask rates on Wednesdays) constitute the primary database of the study. The goal is to establish through cutting-edge econometric procedures three crucial outcomes: the bilateral dependence of the various currency pairs, informational efficiency in the markets of participating currencies, and the long-run bilateral and multilateral linkages of the currencies. When these outcomes are adequately established, the state of current knowledge on the readiness of the region for currency union and eventual monetary integration is expected to be enhanced. The overall result of the study is quite encouraging to supporters of currency union as all of the three outcomes are adequately established empirically. There is a high level of the currencies' bilateral dependence, both in their level values and in their returns; all markets of the participating currencies exhibit informational efficiency, and there exist a number of significant long-run equilibrium relationships linking the floating currencies of the region.

Keywords: ASEAN+3 region, panel unit roots, informational efficiency, Granger causality, cointegration

JEL Classifications: C22, C32, F15, F31

The global financial crisis that plagued Asia in 1997 brought about important changes in the way East Asian countries address their problems. Multilateral financial institutions like the International Monetary Fund (IMF) and the Asian Development Bank (ADB) were not able to adequately attend to Asia's rising needs for funds, prompting affected economies, particularly the hard-hit countries of Southeast Asia, to solve their own financial difficulties by their own means (Lipsey, 2003). The ASEAN+3 cooperation started in 1997 at the height of the crisis but were institutionalized only in 1999 during the ASEAN summit in Manila when the leaders issued a joint statement. From then on, sustained economic, financial, and monetary collaborations have been effected in the pursuit of regional stability and a resolute stand in avoiding the occurrence of similar crises.

The current initiative of the regional grouping of the 10 countries of the Association of Southeast Asian Nations (ASEAN) and the three biggest economies in East Asia—Japan, China, and South Korea—(henceforth the ASEAN+3 Region) to adopt a unified currency has raised a number of concerns. Foremost among which is the apparent lack of financial integration among the participating economies owing to their relative heterogeneity—from the extremely rich countries of Japan, Korea, Singapore, and China to the poor nations of Laos, Cambodia, and Myanmar.

A number of studies have been made to assess the bilateral and multilateral integration of the different economic sectors of the different countries comprising the region (e.g., see Arshanapalli, et. al, 1995; Click & Plummer, 2005; and Manning, 2002). A unified research that will focus on the determination of the long-run relationship among currencies of the region is needed to gain insights on the strength of their long-run linkages.

This study will attempt to empirically answer the question on whether there exists financial integration among ASEAN+3 countries by examining the multilateral movements of the currencies using modern time series econometric techniques. It is expected that the results of the study will provide additional quantitative evidence on the existence (or lack) of monetary and financial integration in the ASEAN+3 region using contemporary high-frequency foreign exchange data covering the time period after a major financial crisis the region has experienced, plus another with worldwide outreach. The study will also supplement the different research efforts by various think-tank groups working on the feasibility of the adoption of a regional monetary unit to be used in macroeconomic surveillance and transactions among participating economies of the region.

Methodology

Economic integration is a complex process any conglomerations of national economies undergo, especially when the membership of the regional grouping includes vastly disparate nations with highly uncoordinated exchange rate arrangements. Such is the case of the 10 countries of the ASEAN, which is composed of high-, middle-, and low-income economies in a move to coalesce with the three East Asian economic giants—Japan, People's Republic of China, and South Korea—to form an expanded ASEAN region.

Quantitatively assessing the extent in which the ASEAN+3 region has attained a sufficient degree of financial and monetary interdependence despite the economic shock of the 1997 crisis and the current worldwide credit crisis may provide useful insights in predicting the success or failure of the coalition. In this study, a number of time series econometric tools are employed on contemporary high-frequency foreign exchange data covering the 15-year period of 1998 to 2012. The scope of the study is limited to the descriptive and inferential analysis of the monetary integration so far attained by the region suggested by the informational efficiency and convergence of the floating currencies in the region.

One of the most avowed objectives of the ASEAN Economic Community is the formation of a smoothly functioning and well-integrated regional financial system, characterized by more relaxed capital account regimes and interlinked capital markets. This study may provide the empirical basis in concluding that despite the occurrence of shocks that challenge the efficient functioning of these markets, which in the past resulted in uncoordinated stock market and exchange rate arrangements (Lipsey, 2003), the existence of long-run linkages among these markets could bring about better and more effective policy coordination

Among the empirical tools used in the study are individual and panel unit root tests (to assess the order of integration of the foreign exchange series), variance ratio (VR) tests (to examine the weak-form efficiency of the foreign exchange markets), and multivariate cointegration tests (to analyze the existence of long-run equilibrium linkages among the exchange rate series). The analytical techniques are employed in an a-theoretic or non-structural basis that allows the historical data to speak for themselves.

Panel Unit Root Tests

Due to the interplay of various market forces, economic and financial time series frequently exhibit the characteristic of having time varying first and second moments. As a result, these variables often display a nonstationary behavioral pattern—a condition that may lead to a breakdown of inference especially when regression-type techniques are employed. When financial series like stock prices or exchange rates are involved, inquiring on the presence of the unit root components of these series is an important requirement of establishing informational efficiency of the underlying asset markets. In this study, the usual individual unit root tests (e.g., ADF, PP, and KPSS tests) are not used but instead, more powerful panel-based tests are considered. In view of the panel structure of the data set and the goal of inferring for a group of countries, these tests are appropriate. In this study, the presence of the unit root component will be empirically determined through a battery of individual (Madalla & Wu, 1999; Im-Pesaran-Shin, 2003) and joint (Levin, Lin, & Chu, 2002) panel unit root tests. The literature points out the superiority of panel-based unit root tests (e.g., Wu & Chen, 1999; Azad, 2009) in terms of power vis-à-vis unit root tests based on individual time series. To conserve space, technical discussion on these tests will not be done, since the study highlights the more important market efficiency analysis of VR tests and cointegration tests.

VR Tests

Lo and MacKinlay (1988) provided the seminal basis for the VR test, which has been used extensively in testing market efficiency of the weak form. This empirical procedure explores the validity of the random walk hypothesis (RWH) by testing the property that the variance of random walk increments is linear in all sampling intervals (i.e., the variance of q-period return is q times the variance of one-period return; Charles & Darne, 2009). Hence, the VR at lag q, which is defined as the ratio between ($1/q$) of the q-period return to the variance of the one-period return should equal to 1 for all q.

If r_t is the return of a currency at time t (t = 1, 2,...,T) and is assumed to be a realization of a stochastic process R_t that follows a martingale difference sequence (MDS), which is known to be uncorrelated and may or may not be conditionally or unconditionally heteroscedastic. Lo and MacKinlay (1988) formulated two test statistics to undertake the VR test for the RWH. The first statistic works under the strong assumption of iid (identically and independently distributed) R_t with constant variance, while the other downgraded the iid assumption to permit general types of time varying volatility that are often seen in financial time series (aka the autoregressive conditional heteroscedasticity [ARCH] effect). The associated null hypothesis under the heteroscedastic assumption is presented below[1].

From the VR statistic,

$$VR(r_t;\mathrm{q}) = \frac{\sum_{t=q}^{T}[\mathrm{r}_t + \ldots + r_{t-q+1} - q\bar{r}]^2}{q\sum_{t=1}^{T}[\mathrm{r}_t - \bar{r}]^2}$$

$$\text{with} \quad \bar{r} = \sum_{t=1}^{T} r_t / T \tag{1}$$

the VR test statistic $M(r_t,\mathrm{q})$ (shown to be asymptotic standard normal z) under the assumption of conditional heteroscedasticity (MDS null) proposed by Lo and MacKinlay (1988) is given by

$$z = M(r_t,\mathrm{q}) = \frac{VR(r_t,\mathrm{q})-1}{\sqrt{\psi(q)}} \quad \text{with} \tag{2}$$

$$\psi(\mathrm{q}) = \sum_{k=1}^{q-1}\left[\frac{2(\mathrm{q}-k)}{q}\right]^2 \xi(k)$$

$$\text{and} \quad \xi(k) = \frac{\sum_{t=k+1}^{T}[r_t-\bar{r}]^2[r_{t-k}-\bar{r}]^2}{\sum_{t=1}^{T}[r_t-\bar{r}]^2}$$

Since the VR restriction holds for every q difference (or logarithmic difference) of the underlying currency series, for $q \geq 1$, it is customary to evaluate test statistics (2) at several selected values of q (in this study, q = 2, 4, 8, and 16).

Chow and Denning (1993) proposed a test statistic used to examine the absolute values of a statistic set of multiple VR statistics (for the different set values of q). The main purpose of this is to control the size (type I error probability) of a joint VR test to be implemented.

The null hypothesis for the Chow–Denning (CD) multiple VR test is set as the joint statement

$$VR(q_i) = 1 \quad \text{for } i = 1, 2, \ldots, \mathrm{m} \tag{3}$$

against the alternative hypothesis

$$VR(q_i) \neq 1 \quad \text{for some holding period } q_i \tag{4}$$

The CD test statistic can be written as

$$CD = \max\left|M(\mathrm{r}_t;q_i)\right| = \max(|\,z\,|) \quad \text{for } 1 \leq i \leq m \tag{5}$$

where

$$MV(\mathrm{r}_t;q_i) = (VR(q_i)-1)\{\sum_{j=1}^{q-1}\left[\frac{2(q_i-j)}{q_i}\right]^2 \xi_{q_i}\}^{-0.5} \tag{6}$$

and

$$\xi_{q_i} = \frac{\sum_{t=q_i+1}^{T} [r_t - \bar{r}]^2 [r_{t-k} - \bar{r}]^2}{\sum_{t=1}^{T} [r_t - \bar{r}]^2} \tag{7}$$

The CD test is anchored on the idea that any decision on the null hypothesis can be based on the maximum absolute value of the individual VR statistic under the MDS assumption of Lo and McKinlay (1988). Under such an assumption, the CD statistic follows the studentized maximum modulus (SMM) distribution with *m* and *T* degrees of freedom (Chow & Denning, 1993), whose critical values are tabulated in Stoline and Ury (1979). The *p*-value for the CD statistic is bounded from above by the *p*-value for the SMM distribution with parameters *m* and *T*, with *T* approaching infinity.

Johansen Multivariate Cointegration

Cointegration is a property of two or more variables that move together through time and, despite following their own individual stochastic trend, will not drift too far apart since they are linked together in some sense. Their long-run equilibrium relationship(s) may be established using appropriate statistical modeling tools. If the variables are not cointegrated, no meaningful economic insights can be drawn in examining their supposed relationship. Only time series variables that are non-stationary in their level values (i.e., I(1)) or lag differenced (i.e., I(p) with p the number of unit roots of the series) can exhibit the property of cointegration.

There are a number of econometric techniques that are available to empirically test the presence of cointegration of a given set of time series variables. Notable among these techniques are the Engle–Granger bivariate test for cointegration and the Johansen multivariate cointegration procedure. The Johansen technique is considered to be the most powerful approach of testing for multivariable cointegration (Lutkepohl, 2005) and is the main tool adopted in this study. The Johansen approach is based on an unrestricted vector autoregressive (VAR) model of nonstationary or differenced stationary time series variables using a relatively long sample period. The first step of the procedure is to ascertain the stationarity of the given variables. This is accomplished by implementing a series of unit root tests. In this study, the panel unit root tests described earlier are employed. After establishing the stationarity or nonstationarity of variables, a trial VAR model is developed and subjected to a battery of diagnostic tests to check for statistical adequacy and explanatory power. This step is repeated until an appropriate model is identified, which will then be used to test for cointegration.

Suppose the vector X_t contains the exchange rate series (which are integrated of the same order, hence with the same number of unit roots) and has the dimension $n \times 1$, where *n* is the number of series in the VAR and *k* is the maximum lag length. Across the time horizon $t = 1,2, 3,\ldots, T$, each series follows a process that is influenced by its own lagged values and the lagged values of the other exchange rate series.

$$X_t = \Psi_1 X_{t-1} + \ldots + \Psi_k X_{t-k} + \varepsilon_t \tag{8}$$

The matrix of coefficients Ψ_k has the dimension $n \times n$. Based on (8), the VAR can be converted into a model of first differences, error correction representation (through the Granger representation theorem). To accomplish this, the lagged values of the series are subtracted from both sides of (8) to come up with the following equation system:

$$\Delta X_t = \sum_{j=1}^{k-1} \Gamma_j \Delta X_{t-j} + \Upsilon X_{t-1} + \varepsilon_t \tag{9}$$

with $\Gamma_j = -I + \Psi_1 + \ldots + \Psi_j$ for $j = 1, 2,\ldots, k-1$ and $\Upsilon = -(I - \Psi_1 - \ldots - \Psi_k)$. According to Johansen and Juselius (1990), the matrices Γ_j contain the information on the short-run adjustment process, while the expression ΥX_{t-1} represents the error correction relationship among the different series; hence, it contains the long-run equilibrium information about the variables (Lutkepohl, 2005). This matrix also indicates the number of cointegrating vectors that can be made if the rank of the matrix is known. This is the reason why the Johansen procedure is anchored on the idea of determining the rank of the matrix Υ, which is equivalent to the maximum number of linearly independent equations the variables can meaningfully form, that is, the number of long-run equilibrium relationships.

For the above reason, a test for cointegration aims at testing the rank of Υ. If the rank is *p* where $0 < p \leq n$, Υ with dimension $p \times r$ can be decomposed into the matrices α and β, such that $\Upsilon = \alpha\beta^{'}$. Through the cointegrating vector β, the nonstationary vector X_t can be made stationary using the transformation $\beta' X_t$. In this case, (9) becomes a vector error correction (VECM) model, with the matrix α describing the speed for each variable to return back (adjust) to equilibrium after a short-run deviation from the long-run relationship. In other words, the elements in α weigh the error correction term in each row of the VECM model (9). Furthermore, the matrix β contains the coefficients of the cointegrating relationship(s) or the coefficients of the equilibrium equation(s). Estimation of the elements of α and β is accomplished through the maximum likelihood estimation (MLE) procedure (Johansen, 1991).

Testing for the cointegration rank can be made by adopting the alternative testing procedures outlined by Johansen (1991). The first test weights the hypotheses of, at most, r cointegration vectors, that is, Rank (Υ) = r, against the alternative of Rank(Υ) > r; that is to say, there are at most r long-run relations at the null. This particular test is based on a likelihood ratio test and is called the trace statistic test:

$$\lambda_{trace} = -T \sum_{t=r+1}^{p} \ln((1-\hat{\lambda}_t) \qquad (10)$$

In addition to this test, Johansen (1991) also proposed another test for the same purpose of finding the number of cointegrating vectors in a VAR model of n time series, which he called the maximum eigenvalue test:

$$\lambda_{\max} = -T \ln(1-\hat{\lambda}_{r+1}) \qquad (11)$$

Johansen and Juselius (1990) showed that (10) and (11) are asymptotic χ^2 with $p-r$ degrees of freedom. They suggested the use of both tests simultaneously as each requires the same intermediate input information but may give different (but not too detached) results. These two test statistics will be used in the study to empirically establish the presence of long-run linkages among the floating ASEAN+3 currencies.

Pair-Wise Granger Causality Analysis

A secondary analysis performed under the VAR framework applied in the cointegration study is a series of Granger causality tests between pairs of participating currencies. This analytical procedure is used to determine whether a change in one variable causes a change in or helps to predict the other variable. For each equation in the VAR, representing each of the currencies as dependent variable, Wald (F) statistics for the joint significance of each of the other lagged endogenous variables in that equation reveal the statistical causality (in a Granger sense) of the RHS (right-hand side) currency on the LHS (left-hand side) currency of the equation.

The applications of the above analytical methodologies are done without any explicit theoretical or structural framework in mind; they are implemented to the available data as inference procedures for the purpose of establishing long-run linkages of floating currencies of the ASEAN+3 region.

Data

Among the 13 economies comprising the ASEAN+3 region, 7 have sufficient historical data of floating exchange rate regimes covering the period of 1998–2012. These countries are Brunei Darussalam, Japan, Korea, Singapore, Indonesia, the Philippines, and Thailand, whose respective currencies—Brunei dollar (BND), Japanese yen (JPY), Korean won (KRW), Singapore dollar (SGD), Indonesian rupiah (IDR), Philippine peso (PHP), and Thai baht (THB) are under either the freely floating or the managed float regimes. Please see Appendix A for the IMF classified currency regimes of all of the ASEAN+3 countries (Rufino & de Guia, 2011).

The daily interbank call rates of these currencies vis-à-vis the US dollar (nominal currency value per US dollar) for the period of January 1998 to December 2012 constitutes the primary database of the study. The data source is OANDA—the world's most trusted source of filtered currency and foreign exchange market information. The weekly data (average of bid and ask rates for Wednesdays) are used in the analysis instead of daily observations to avoid the built-in biases associated with daily series (e.g., bid and ask spread, asynchronous prices, etc.; Lo & McKinlay, 1988; Azad, 2008; Darrat & Zhong, 2000). Consequently, balanced panel data of 781 (January 7, 1998, to December 26, 2012) weekly observations for each of the seven currencies were utilized in the study.

Results and Discussions

Stylized Facts About the Floating ASEAN+3 Currencies During the Sample Period

Descriptive analysis of the pattern of movements of the variables under study often reveals useful insights relevant to the goals of the research. Figure 1 depicts the line graphs of the weekly nominal rates of the participating currencies against the US dollar. Ocular inspection of the graphs may give a general impression that the movements of currencies are erratic. All currencies appear to be drifting in the same general direction, that is, long-term strengthening against the US dollar, with pronounced local peaks and troughs, particularly their simultaneous dips during the early part of 2008. All currencies weakened during most of the later part of 2008 until around 2010 when a long-term strengthening again set in. Such general pattern of the exchange rate series may give an initial, although hazy, evidence of their long-run linkages. When analysis is focused on the simple pair-wise correlations of FX series showed in Table 1, only two currency pairs (IDR vs. BND and IDR vs. SGD) out of a total of 21 pairs registered statistically insignificant correlations. The other 19 currency pairs have highly significant correlations ($p \leq 0.0063$), for a simple bilateral linkage rate of 90.48%.

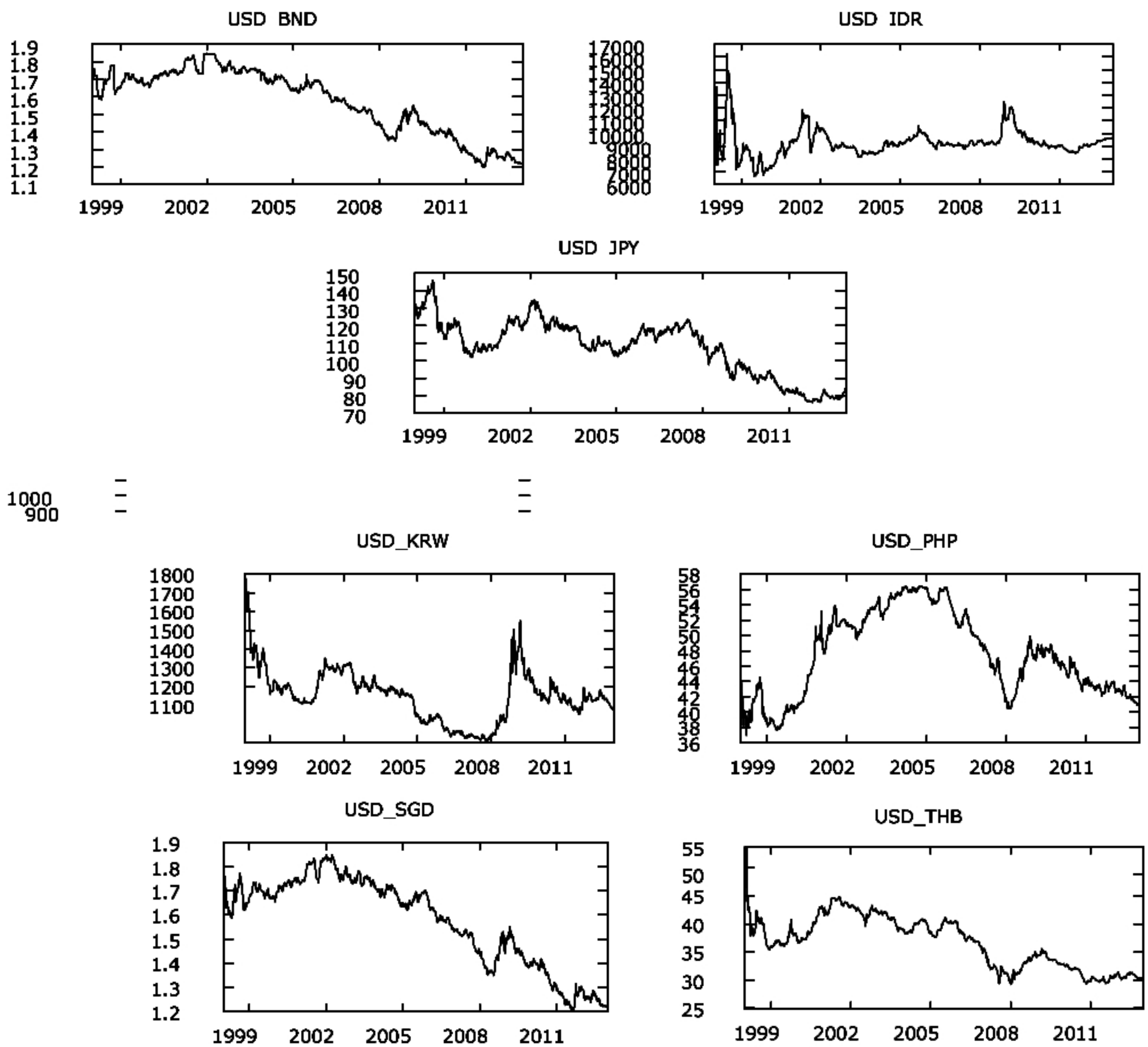

Figure 1. Line graphs of floating currencies of ASEAN+3 region, January 7, 1998, to December 26, 2012.

Table 1. *Correlation Matrix of Floating ASEAN+3 Currencies*

Correlation p-Value	Weekly Nominal FX Rates, January 7, 1998–December 26, 2012						
	BND	IDR	JPY	KRW	PHP	SGD	THB
IDR	0.027066	1.000000					
	0.4498	—					
JPY	0.834540	0.149858	1.000000				
	0.0000	0.0000	—				
KRW	0.310247	0.314394	0.178999	1.000000			
	0.0000	0.0000	0.0000	—			
PHP	0.454170	0.173707	0.258271	-0.097624	1.000000		
	0.0000	0.0000	0.0000	0.0063	—		
SGD	0.997137	0.028427	0.833748	0.302984	0.458927	1.000000	
	0.0000	0.4273	0.0000	0.0000	0.0000	—	
THB	0.914546	0.151753	0.737824	0.444127	0.516085	0.917237	1.000000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	—

Table 2. *Pair-Wise ASEAN+3 Floating Currencies Granger Causality Tests (p-values)*

Ho: Column Currency Does Not Granger Cause	Ho: Row Currency Does Not Granger Cause						
	IDR	**JPY**	**KRW**	**PHP**	**SGD**	**THB**	**BND**
IDR		*0.30810*	*0.11510*	0.05960	0.00140	0.00060	0.01350
JPY	*0.16080*		0.05090	*0.20640*	*0.634400*	*0.78360*	0.00002
KRW	0.00070	0.00009		*0.15690*	0.00230	*0.13430*	0.00190
PHP	0.00020	*0.44320*	*0.82240*		0.09750	*0.92190*	*0.73460*
SGD	0.00000	0.00070	0.00030	0.07680		0.00020	0.00000
THB	0.00000	0.04700	0.00100	0.00002	0.01490		0.00050
BND	0.00000	*0.12950*	0.02530	0.00240	*0.34040*	0.00390	

(Italized figures indicate insignificance)

In order to fine tune the results of the correlation analysis, a Granger statistical causality analysis is performed on the currency pairs. This procedure will provide direction of statistical causality whenever there is bilateral linkage. The results of this analysis are presented in Table 2, wherein total of 13 currency pairs register insignificant ($p > 0.10$) Granger causality out of 42 possible directional pairs, for a lesser linkage rate of 69.05%.

Plotting the logarithmic first difference of the currencies over time, which is mathematically synonymous to their continuously compounded one holding period (weekly) returns, Figure 2 emerged. When these return series apparently exhibit mean

Table 3. *Correlation Matrix of Returns of Floating ASEAN+3 Currencies*

Correlation p-value	Weekly Returns, January 7, 1998–December 26, 2012						
	RETBND	**RETIDR**	**RETJPY**	**RETKRW**	**RETPHP**	**RETSGD**	**RETTHB**
RETIDR	0.291229	1.000000					
	0.0000	—					
RETJPY	0.212346	0.079941	1.000000				
	0.0000	0.0255	—				
RETKRW	0.467262	0.272368	0.000452	1.000000			
	0.0000	0.0000	0.9899	—			
RETPHP	0.310356	0.297755	0.074348	0.431822	1.000000		
	0.0000	0.0000	0.0378	0.0000	—		
RETSGD	0.719863	0.307851	0.310358	0.508267	0.407619	1.000000	
	0.0000	0.0000	0.0000	0.0000	0.0000	—	
RETTHB	0.367369	0.444911	0.158535	0.338614	0.464052	0.496675	1.000000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	—

Table 4. *Stylized Facts of Returns of ASEAN+3 Floating Weekly Exchange Rates Weekly, January 7, 1998–December 26, 2012*

	RETBND	**RETIDR**	**RETJPY**	**RETKRW**	**RETPHP**	**RETSGD**	**RETTHB**
Mean	−0.000419	0.000208	−0.000572	−0.000654	−0.000124	−0.000480	−0.000704
Median	0.000000	0.000380	−0.000184	−0.001251	0.000000	−0.000687	−0.000589
Maximum	0.061738	0.433359	0.047869	0.098841	0.053584	0.037815	0.060954
Minimum	−0.078103	−0.407665	−0.085225	−0.131233	−0.079182	−0.038849	−0.130444
Std. Dev.	0.008554	0.037224	0.014072	0.016961	0.010942	0.007629	0.012098
Skewness	−0.446934	0.735091	−0.628701	−0.022800	−0.670309	0.016283	−2.433896
Kurtosis	16.89657	53.34149	5.690101	14.43224	12.15284	5.817923	30.07028
Jarque–Bera	6310.275	82539.57	286.9427	4253.133	2784.644	258.4377	24617.62
p-value	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
ARCH(14)	754.681	594.358	749.991	354.637	748.416	139.413	114.452
p-value	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

reversion to zero level, one may get an impression that the exchange rates have a unit root component—an indication of their individual random walk movements. Additionally, as observed in most asset price series, an episodic flurry of activities during certain periods is also seen in the graphs of the return series. Most of these observed volatilities occurred during the height of the crisis periods in the early part of 1998 and in the later part of 2008. Such episodes are particularly strong for the international currencies JPY, KRW, and SGD. These volatility patterns suggest the heteroscedastic nature of the return series commonly referred to as the ARCH effect, which was validated empirically in Table 4.

The correlation matrix of returns featured in Table 3 shows that returns are pair-wise highly correlated across currencies with the same algebraic signs; that is, returns move in the same direction indicating a certain level of convergence. Only the returns of the currency pairs JPY–KRW appear to be statistically unrelated.

Results on the Lagrange multiplier ARCH (14) tests demonstrate the extremely high statistical significance

Table 5. *Panel Unit Root Tests on ASEAN+3 Floating Currencies*

Summary for Level Variables Method	Statistic	*p*-value**	Cross-Sections	Observations
Null Hypothesis: Unit Root (Assumes Common Unit Root Process)				
Levin, Lin, & Chu t^*	2.09876	0.9821	7	5410
Null Hypothesis: Unit Root (Assumes Individual Unit Root Process)				
Summary for First Differences Method	Statistic	*p*-value**	Cross-Sections	Observations
Null: Unit Root (Assumes Common Unit Root Process)				
Levin, Lin, & Chu t^*	−48.7553	0.0000	7	5407
Null: Unit Root (Assumes Individual Unit Root Process)				
Im, Pesaran, & Shin W-stat	−47.5649	0.0000	7	5407
ADF–Fisher χ^2	855.851	0.0000	7	5407
PP–Fisher χ^2	1206.87	0.0000	7	5460
**p-values for Fisher tests are computed using an asymptotic χ^2 distribution. All other tests assume asymptotic normality.				
Im, Pesaran, & Shin W-stat	0.08445	0.5337	7	5410
ADF–Fisher χ^2	18.1263	0.2011	7	5410
PP–Fisher χ^2	50.6065	0.0000	7	5467

of the ARCH effect in all currencies with p-values equivalent to zero at seven significant digits. This observed manifestation may prove to be useful in the analysis of the martingale properties (informational efficiency) of the exchange rates. Other statistics presented in Table 4 quantitatively confirm most of our cursory observations on the graphs of returns (Fig. 2). Mean reversion to zero level is confirmed as both mean and median returns in all currencies are almost 0. Excessive departure from normality is observed in all return series with all Jarque–Bera statistics depicting extreme significance ($p < 0.000001$). These features of the return distribution are consistent with the concept of the weak form market efficiency hypothesis, popularly known as the RWH introduced by Samuelson (1965) and Fama (1965).

Unit Root Properties of the Exchange Rate Series

Results of the application of the various panel unit root tests on the working sample are all revealed in Table 5. The top part of the table deals with the application of the tests on the level series, while the bottom portion presents the results of the different panel unit root tests on the first differenced series. Insignificant results on the level series confirm the presence of unit root component in the level or the untransformed exchange rate series, while significant results in the first differenced series validate the existence of a single unit root. Heavier consideration is often placed on the results of the Levin, Lin, and Chu test (common unit process assumption for the cross section entities) as well as on the Im, Pesaran, and Shin test (individual unit root process assumption for each cross section entity; Wu & Chen, 1999). The results are unmistakable—the floating ASEAN+3 currencies are nonstationary, each with a single unit root, which implies that their returns are characterized by the white noise process. Hence, the floating currencies of the expanded ASEAN region possess the necessary condition for EMH—the existence of the unit root component (Azad, 2009), thus paving the way for testing for the presence of uncorrelated increments of the exchange rate series—the sufficiency conditional .

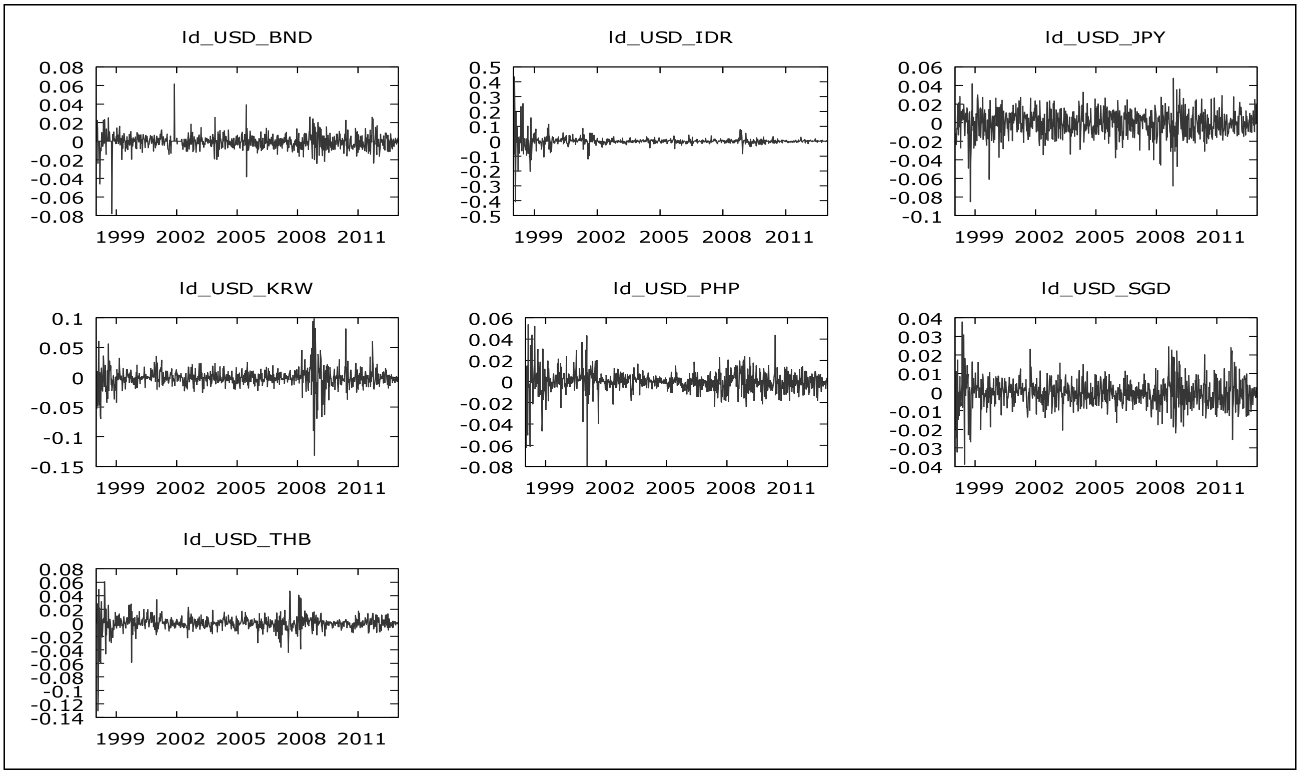

Figure 2. Line graphs of the continuously compounded one-week holding period returns of ASEAN+3 floating currencies.

VR Tests Results

To ascertain the presence of uncorrelated increments in each of the currencies, the VR test, discussed in the Methodology section is employed. In this study, the robust version of the test is used since the stylized facts on the different currencies and their returns show the presence of an unknown form of heteroscedasticity in the exchange rate series. Empirical tests on this phenomenon using the available data confirm the significance of the ARCH effects in all series; hence, tests for the presence of uncorrelated increments in the individual currencies are assessed under the MDS null hypothesis. The procedure to test the MDS null proposed by Lo and McKinlay (1988) is applied together with the Chow-Denning (CD) multiple VR procedure; the results of both tests are presented in Table 6.

Under the null hypothesis that each currency follow an MDS—a version of the RWH that is immune to the ill inferential effects of the ARCH—whose presence is earlier established analytically, no evidence whatsoever was found to reject such hypothesis, across the board in all sampling intervals (q). Both the Lo–MacKinlay individual VR tests and the CD multiple VR tests confirm the validity of the MDS null. With the established presence of the unit root component and the martingale properties in each of the floating currencies in the ASEAN+3 region, it is now safe to conclude that foreign exchange markets in the region are informationally efficient. This means that all exchange rates fully and instantaneously reflect all available and relevant information, such that adjustments are immediate in a manner that returns cannot be reliably predicted (Samuelson, 1965; Fama, 1965).

The central research agenda of the study is to provide analytical evidence on the existence of steady state linkages among currencies of the expanded ASEAN region. To accomplish such a task, the Johansen multivariate cointegration technique is employed in the study. The results of the two tests proposed by Johansen (1991)—the trace test and the maximum eigenvalue test, as seen in Table 7—reveal the presence of at most four cointegrating equations linking the various currencies. This means that the amount of information available may allow us to extract at most four equilibrium relationships

Table 6. *Individual and Joint VR Tests of the Random Walk Properties of Floating ASEAN+3 Currencies*

Ho: Brunei Dollar is a Martingale				
Period (*q*)	2	4	8	16
Var. Ratio	1.03431	1.06930	1.05025	0.91932
Std. Error	0.05630	0.09332	0.12909	0.18156
z-Statistic	0.60949	0.74268	0.38931	−0.44440
p-value	0.54220	0.45770	0.69700	0.65680
CD Joint Test	Value	df	*p*-value	
Max |*z*| (at period 4)*	0.742677	781	0.9135	

Ho: Philippine Peso is a Martingale				
Period (q)	2	4	8	16
Var. Ratio	0.94933	0.98928	0.99972	1.09859
Std. Error	0.07284	0.12370	0.17900	0.24493
z-Statistic	−0.69562	−0.08667	−0.00156	0.40253
p-value	0.48670	0.93090	0.99880	0.68730
CD Joint Test	Value	df	*p*-value	
Max |*z*| (at period 2)*	0.695624	781	0.9306	

Ho: Indonesian Rupiah is a Martingale				
Period (*q*)	2	4	8	16
Var. Ratio	1.04231	0.73262	0.81669	0.67957
Std. Error	0.15048	0.29914	0.41971	0.52281
z-Statistic	0.28116	−0.89384	−0.43675	−0.61289
p-value	0.77860	0.37140	0.66230	0.53990
CD Joint Test	Value	df	*p*-value	
Max |*z*| (at period 4)*	0.893835	781	0.8439	

Ho: Singaporean Dollar is a Martingale				
Period (*q*)	2	4	8	16
Var. Ratio	1.06341	1.15784	1.13201	1.04190
Std. Error	0.04978	0.09744	0.15153	0.21477
z-Statistic	1.27377	1.61983	0.87122	0.19509
p-value	0.20270	0.10530	0.38360	0.84530
CD Joint Test	Value	df	*p*-value	
Max |*z*| (at period 4)*	1.619832	781	0.3591	

Ho: JPY is a Martingale				
Period (*q*)	2	4	8	16
Var. Ratio	1.06775	1.10384	1.08881	1.18314
Std. Error	0.04915	0.08677	0.13487	0.19710
z-Statistic	1.37862	1.19666	0.65851	0.92917
p-value	0.16800	0.23140	0.51020	0.35280
CD Joint Test	Value	df	*p*-value	
Max |*z*| (at period 2)*	1.378615	781	0.5209	

Ho: Thai Baht is a Martingale				
Period (*q*)	2	4	8	16
Var. Ratio	1.07335	1.12042	1.12216	0.97600
Std. Error	0.18648	0.30601	0.40315	0.49350
z-Statistic	0.39335	0.39352	0.30301	−0.04863
p-value	0.69410	0.69390	0.76190	0.96120
CD Joint Test	Value	df	*p*-value	
Max |*z*| (at period 4)*	0.393515	781	0.9912	

Ho: KRW is a Martingale				
Period (*q*)	2	4	8	16
Var. Ratio	0.99821	0.97413	0.97906	0.88953
Std. Error	0.11070	0.20647	0.31278	0.41834
z-Statistic	−0.01618	−0.12530	−0.06694	−0.26406
p-value	0.98710	0.90030	0.94660	0.79170
CD Joint Test	Value	df	p-value	
Max |z| (at period 16)*	0.264058	781	0.9981	

Table 7. *Johansen Multivariate Cointegration Tests on ASEAN+3 Floating Currencies*

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	**Eigenvalue**	**Trace Statistic**	**0.05 Critical Value**	***p*-value.****
None *	0.112318	230.1860	125.6154	0.0000
At most 1 *	0.069722	138.0892	95.75366	0.0000
At most 2 *	0.041235	82.22315	69.81889	0.0037
At most 3 *	0.031072	49.67233	47.85613	0.0334
At most 4	0.024109	25.27278	29.79707	0.1519
At most 5	0.008050	6.408295	15.49471	0.6473
At most 6	0.000208	0.160639	3.841466	0.6886

Trace test indicates 4 cointegrating equations at the 0.05 level.

*Rejection of the hypothesis at the 0.05 level.

**MacKinnon–Haug–Michelis (1999) *p*-values.

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 Critical Value**	***p*-value****
None*	0.112318	92.09680	46.23142	0.0000
At most 1*	0.069722	55.86604	40.07757	0.0004
At most 2	0.041235	32.55082	33.87687	0.0713
At most 3	0.031072	24.39955	27.58434	0.1214
At most 4	0.024109	18.86448	21.13162	0.1008
At most 5	0.008050	6.247656	14.26460	0.5817
At most 6	0.000208	0.160639	3.841466	0.6886

Max-eigenvalue test indicates 2 cointegrating equations at the 0.001 level.

*Rejection of the hypothesis at the 0.001 level.

(equations) linking the seven currencies under investigation. Such preponderance of long-run relationships is plausible due to the underlying structural relationships (economic theories) linking the different variables in the set (King et. al., 1991). This outcome is not entirely unexpected in light of the results of the analysis of pair-wise correlations (Tables 1 and 3) and Granger causality tests (Table 2), which put the level of the currencies' bilateral dependence at 90.48% and 85.72%, respectively.

Concluding Remarks

The study represents an attempt to analytically evaluate the extent with which the expanded ASEAN grouping, euphemistically labeled as the ASEAN+3 region, has attained long-run currency linkages—an important requisite for an eventual currency union and monetary integration. The study used high-frequency interbank call rates (nominal exchange rate vis-à-vis the US dollar) data on seven floating currencies of the region with sufficient historical time series covering the period of 1998 to 2012 (weekly: January 7, 1998, to December 26, 2012; average of bid and ask rates on Wednesdays). The goal is to establish through state-of-the-art econometric procedures three crucial outcomes: (1) bilateral dependence of currency pairs, (2) informational efficiency of the participating currencies, and (3) long-run multilateral linkages of the currencies. When these outcomes are adequately established, as this study has demonstrated using cutting-edge econometric procedures, the state of the current knowledge on the readiness of the region for currency union and eventual monetary integration will be enhanced.

Note

[1] We focus only on the test statistic robust under heteroscedasticity as all return series display ARCH effect

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Appendix A

ASEAN+3 Countries, Local Currency, and Exchange Rate Regime

Country	Local Currency		Exchange Rate Regime[1]
Brunei	BND	Brunei Dollar	Managed Float
Cambodia	KHR	Cambodian Riel	Managed Float
China	CNY	Chinese Yuan Renminbi	Fixed Peg Arrangement (against a single currency)
Indonesia	IDR	Indonesian Rupiah	Managed Float
Japan	JPY	Japanese Yen	Independently Floating
Laos	LAK	Laos Kip	Managed Float
Malaysia	MYR	Malaysian Ringgit	Fixed Peg Arrangement (against a single currency)
Myanmar	MMK	Myanmar Kyat	Managed Float
Philippines	PHP	Philippine Peso	Independently Floating
Singapore	SGD	Singapore Dollar	Managed Float
South Korea	KRW	South Korean Won	Independently Floating
Thailand	THB	Thai Baht	Managed Float
Vietnam	VND	Vietnamese Dong	Fixed Peg Arrangement

[1]*Source: International Monetary Fund—Classification of Exchange Rate Arrangements*