Australian Journal of Basic and Applied Sciences, 9(8) Special 2015, Pages: 145-150

ISSN:1991-8178

Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com

The Behaviour of Exchange Rate and Interest Rate Differential in Malaysia: Evidence from Wavelet Analysis

[1]Lalitha Dhamotharan and [2]Mohd Tahir Ismail

[1] *University Sains Malaysia, School of Mathematical Sciences, 11700 Penang, Malaysia*
[2]*University Sains Malaysia, School of Mathematical Sciences, 11700 Penang, Malaysia.*

ARTICLE INFO

Article history:
Received 12 February 2015
Accepted 1 March 2015
Available online 28 March 2015

Keywords:
Exchange rate, Interest Rate Differential, Granger Causality, Wavelet Analysis

ABSTRACT

Background: The general consensus from a plethora of literatures is that the relationship between exchange rate and interest rate differential is ambiguous. However, a close examination of the literature reveals that the results have been elusive due to one dimensional analyses of conventional econometric methods that are unable to decipher the complex time-scale relationship between these variables. **Objective:** The present study investigates the linear and nonlinear causality between nominal exchange rate and interest rate differential for Malaysia (*vis-à-vis* the US) using wavelet analysis during the period 1990 to 2013. **Results:** The key empirical finding from wavelet decomposed data along with the nonlinear Granger causality tests reveal reinforcing evidence between exchange rate and interest rate differential during the short-term (2-, 4-month periods); while nominal interest rate differential Granger causes spot exchange rate in the longer-term (16-month period). **Conclusion:** We find that time scale decomposition is crucial when examining complex nonlinear economic variables.

To Cite This Article: Lalitha Dhamotharan and Mohd Tahir Ismail., The Behaviour of Exchange Rate and Interest Rate Differential in Malaysia: Evidence from Wavelet Analysis. ***Aust. J. Basic & Appl. Sci.,*** *9(8): 145-150, 2015*

INTRODUCTION

The interests in the relationship between exchange rates and interest rates differentials lies in its role in affecting a country's monetary and economic policies. The persistent current account deficit of South-east Asian economies during the past decade or so have revealed the importance of these variables in making or breaking a nation especially during the Asian financial crisis in 1997/1998. The ability of the monetary authorities to pursue policies aimed at maintaining economic sustainability while retaining its exchange rate competitiveness is absolutely vital. However, the relationship between the variables have been subject to debate academically with no real consensus on the underlying relationship. Several factors such as utilization of different assumptions and proxies, one-dimensional methodologies, nonlinear characteristics of the data as well as ignoring the complex and interchanging relationship on time-scale domain have been identified (Almasri & Shukur, 2003; Gencay, *et al*., 2002; Hacker, *et al*., 2012; Mahajan & Wagner, 1999; Nakagawa, 2002). The accurate unveiling of the linkage between exchange rate and interest rate differential provides insight especially for a small country like Malaysia that follows a liberal exchange rate control regime to embark especially in the current turbulent global economic environment. In this paper we seek to investigate the relationship between Malaysian Ringgit/US Dollar spot exchange rate and nominal interest rate differential using a novel approach known as wavelet analysis.

Empirical Model:

Naturally, the model begins with the uncovered interest parity condition (UIP) that governs the underlying relationship between spot exchange rates and nominal interest rate differential. According to the UIP, the nominal exchange rate adjustment is expected once the nominal interest rate differential between domestic and foreign country exists. Behold that $(*)$ from herein denotes the foreign-country variable.

$$E_t(s_{t+k} - s_t) = ({}_k i_t - {}_k i_t^*) + \rho_t \quad (1)$$

E_t = conditional expectation operator during time-t

s_t = logarithm of the nominal exchange rate

${}_k i_t$ = period-*t* yield to maturity on *k*-period nominal interest rate

ρ_t = exchange rate risk premium

Corresponding Author: Lalitha Dhamotharan, University Sains Malaysia, School of Mathematical Sciences, 11700 Penang, Malaysia

The UIP in Equation (1) articulates that nominal interest rate differential equals the expected change in the nominal exchange rate, while the risk premium is assumed to be constant. The expected change of the spot rate is proportional to the long-run rate and current spot rate, while the long-run exchange rate is assumed unknown and constant. The interest rate differential $({}_k i_t - {}_k i_t^*)$ is computed as the difference between one plus the U.S interest rate and one plus the foreign interest rate expressed in logarithm based on the precise theoretical definition as follows:

$$(1 + i_t) = (E^e / E)(1 + i_t^*) \quad (2)$$

where the expected exchange rate (E^e) is an approximation (Hacker, *et al.*, 2012). There are two assumptions to test Equation (1); that is the foreign market is weakly efficient; and second, the mathematical conditional expectation operator is based upon the true probability distribution underlying the events that occur in the financial markets (Cumby & Obstfeld, 1981).

Research Design:

A combination of conventional and nonconventional statistical methods were employed to empirically analyse the relationship between spot exchange rates and interest rate differentials. The logarithmic data were decomposed based on the discrete wavelet analysis. Following the methods specified by Gencay *et al*. (2002), let y be a dyadic length vector with $N = 2^J$ observations and w represent the discrete wavelet coefficients of the N-length vector that will be obtained by means of $w = Wy$. The wavelet coefficients are structured into $J + 1$ vectors illustrated as follows:

$$w = [w_1, w_2, \dots, w_J, v_J]^T \quad (3)$$

w_j $= N/2^j$ length vector of wavelet coefficient with scale length $\lambda_j = 2^{j-1}$

v_J $= N/2^J$ length vector of scaling coefficient with scale length with $2^J = 2\lambda_J$

The wavelet and scaling coefficients that make up matrix W are sorted as:

$$h_1 = [h_{1,N-1}, h_{1,N-2}, \dots, h_{1,1}, h_{1,0}]^T \quad (4)$$

where h_1 represent the inversely ordered vector of zero-padded unit scale wavelet filter coefficients. Hence, the matrix W_1 with $N \times N/2$ dimensions is constructed by circularly shifting the vector h_1 to obtain $N/2$ types of h_1 that follows:

$$W_1 = \left[h_1^{(2)}, h_1^{(4)}, \dots, h_1^{(N/2-1)}, h_1\right]^T \quad (5)$$

Now, in order to conclude the construction of the orthonormal matrix W, wavelet filter coefficients for scales j (with $j = 1, \dots, J$) were be computed using wavelet filter $h_{j,l}$ for scale $\lambda_j = 2^{j-1}$ and scaling filter g_J for scale λ_j. The DWT is implemented via pyramid algorithm introduced by Mallat (1989) as shown in Figure 1.

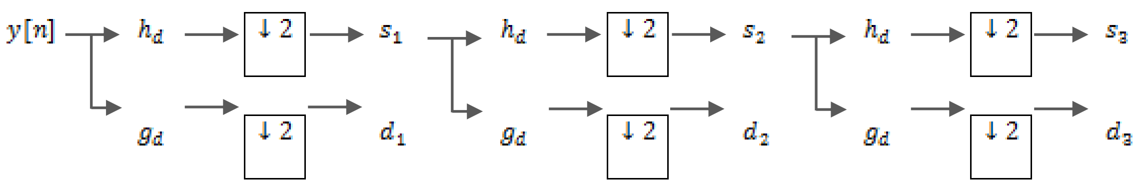

Fig. 1: Mallat Decomposition Tree for DWT (Level 3).

The convolving and down sampling iterations by the pyramid algorithm using data vector y_t along with wavelet filter h_l and scaling filter g_l produces wavelet coefficients and scaling coefficients:

$$w_{j,t} = \sum_{l=0}^{L-1} h_l v_{j-1,(2t+1-l) \bmod N_{j-1}} \quad (6)$$

$$v_{j,t} = \sum_{l=0}^{L-1} g_l v_{j-1,(2t+1-l) \bmod N_{j-1}} \quad (7)$$

with $t = 0, \dots, N_{j-1}; v_{0,t} = y_t$ and $N_j = N/2^j$. Next, the multi resolution analysis, which is the additive decomposition of a time series is conducted using DWT. Let the j-th wavelet detail be defined as $d_j = W_j^T w_j$ for $j = 1, \dots, J$ that is associated with changes in time series $\{y_t, t = 0, \dots, N-1\}$ at scale λ_j. For a length of $N = 2^J$ vector observations, the final wavelet detail is $d_{J+1} = V_J^T V_J$ is equivalent to the sample mean. The MRA is defined as the linear combination of wavelet detail coefficients for each observation of y_t:

$$y_t = \sum_{j=1}^{J+1} d_{j,t} \quad (8)$$

with $t = 0, \ldots, N-1$. The wavelet smooth is defined as $s_j = \sum_{k=j+1}^{J+1} d_k$ for $0 \leq j \leq J$ and s_{J+1} is a vector of zeros. The variations of a scale are captured by d_j, whereas s_J represent the cumulative sum of the variations.

The wavelet decomposed data obtained from the MRA were then examined using the conventional bivariate vector auto regressive (VAR) model to tests for linear and nonlinear Granger causality at various scales. Prior to running the tests, an integrated procedure of selecting an appropriate model is conducted by examining several facets of the data including the integration order, serial correlation and cointegration. Monthly data of spot exchange rates and 3-month money market rates for the interest rate differential variable were obtained from four secondary sources for both Malaysia and US (viz., Thomson Reuters DataStream, Bloomberg, IMF via the CEIC WebCDM Global Database and OECD); during the period of January 1990 to December 2013.

Empirical Results And Discussion:

Table 1 gives the summary statistics for the spot exchange rate and nominal interest rate differential. The measures of skewness (-0.30 and 0.32 respectively) indicate that the time series have non-symmetric distributions as the exchange rate variable is skewed to the left as opposed to the interest rate differential variable that is skewed to the right. The values of kurtosis (1.56 and 2.25 respectively) suggest that the data has flatter than a normal distribution with a wider peak indicating a platikurtic distribution. The Jarque-Bera (1994) test rejects the null indicating that the data is not normally distributed; while the results for the Breush-Godfrey Lagrange Multiplier (LM-test) (Godfrey, 1988) tests reveal that there is no serial correlation amongst the variables.

Table 1: Summary statistics.

Exchange Rate	Mean	1.17
	Standard deviation	0.16
	Skewness	-0.30
	Kurtosis	1.56
	Jargque_Bera test	29.16***
Interest Rate Differential	Mean	-0.01
	Standard deviation	0.019
	Skewness	0.32
	Kurtosis	2.25
	Jargque_Bera test	11.76***
Exchange Rate-Interest Rate Differential	Breush-Godfrey LM-test	3.97

Note: The null for the Jarque Bera-test is H_0: normal distribution while the null hypothesis for the Breush Godfrey LM-test is H_0: no serial correlation up to lag order 12. Both tests follows a χ^2 distribution. ***, ** and * denote significance at 1%, 5% and 10% level, respectively.

The logarithmic series are reconstructed into scales using wavelet analysis allowing insight to the relationship between exchange rates and interest rate differential based on a time-scale variation. Figure 1 below show the plots of the discrete wavelet transform decomposition for scales d_1 to s_4 during the period of 1990 to 2013 using Symlet 8 wavelet filter. The illustration provides an overview of the how the different scales captures the varying information contained in the natural logarithmic series based on the time period of 2-, 4-, 8- and 16 months respectively.

To determine the underlying process of the data, three tests were employed, known as the Augmented Dickey-Fuller (1979; 1981), Phillips-Perron (1988) as well as Kwiatkowski, Phillips, Schmidt and Shin (1992) tests denoted as ADF, PP and KPSS respectively. Due to the low power of these tests, it is vital to employ all three tests to prevent arbitrarily rejecting the null especially for borderline processes. Note that when the tests (ADF and/or PP as well as KPSS) acts in unison in either rejecting or accepting the null, this leads to the conclusion of either *I*(d)-type process or inconclusive evidence on the underlying process, respectively. Whereas if the tests are contrasting, that is (i) either ADF- or PP-tests rejects the null while KPSS-test accepts it; or (ii) either ADF- and PP-tests accepts the null while the KPSS-test rejects it; the process is said to be stationary *I*(0) or nonstationary *I*(1) respectively. Based on the results in Table 2 above, it is clear that the logarithmic variables are nonstationary, whereas the wavelet decomposed variables for d_1 to d_4 be stationary and s_4 is nonstationary. Hence for the *I*(1) or nonstationary variables the Johansen cointegration test (Johansen, 1988) is performed. Based on results of the trace statistic in Table 3, the variables are cointegrated.

Australian Journal of Basic and Applied Sciences, 9(8) Special 2015, Pages: 145-150

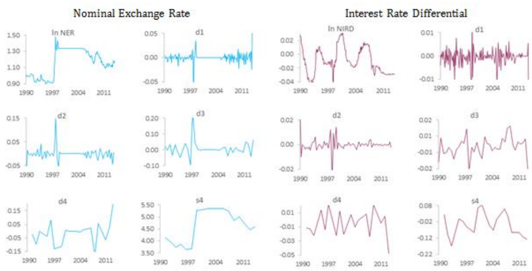

Fig. 1: Discrete Wavelet Transform Decomposition at scales d1, d2, d3, d4 and s4 using Symlet 8 filter.

Table 2: Unit Root Tests.

	$H_0: I(1)$		$H_0: I(1)$		$H_0: I(0)$	
	τ_τ	τ_μ	$Z(t_{\tilde{\alpha}})$	$Z(t_{\alpha^*})$	$\hat{\eta}_\tau$	$\hat{\eta}_\mu$
Exchange Rate						
$\ln NER$	-1.51	-1.60	-1.50	-1.60	0.37***	0.83***
$d_1 NER$	-13.45***	-13.42***	-14.52***	-14.07***	0.12	0.33
$d_2 NER$	-8.45***	-8.40***	-14.06**	-12.22***	0.13	0.14
$d_3 NER$	-7.20***	-7.32***	-7.20***	-7.32***	0.06	0.07
$d_4 NER$	-4.16**	-3.82**	-4.11**	-3.75**	0.10	0.28
$s_4 NER$	-1.30	-1.45	-1.30	-1.45	0.58***	2.02***
Interest Rate Differential						
$\ln NIRD$	-1.51	-1.60	-1.56	-1.64	0.42***	0.95***
$d_1 NIRD$	-14.50***	-14.61***	-14.70***	-14.87***	0.10	0.12
$d_2 NIRD$	-16.90***	-16.93***	-29.17***	-22.54***	0.121	0.15
$d_3 NIRD$	-5.44***	-5.50***	-5.42***	-5.50***	0.08	0.24
$d_4 NIRD$	-6.95***	-7.28***	-7.49***	-7.39***	0.10	0.10
$s_4 NIRD$	0.45	-0.36	-3.44	-2.43	4.29***	0.95***

Note: τ_τ, τ_μ, $Z(t_{\tilde{\alpha}})$, $Z(t_{\alpha^*})$, $\hat{\eta}_\tau$ and $\hat{\eta}_\mu$represent the test statistics with constant and time trend as well as constant only for the ADF-, PP- and KPSS-tests respectively. The null is $H_0: \gamma = 1, \alpha_1 = 0 \Rightarrow y_t \sim I(1)$without drift and $H_1: |\gamma| < 1 \Rightarrow y_t \sim I(0)$with zero mean for a constant term; while the null for a constant term and time trend is $H_0: \gamma = 1, \alpha_2 = 0 \Rightarrow y_t \sim I(1)$ with drift and $H_1: |\gamma| < 1 \Rightarrow y_t \sim I(0)$ with deterministic time trend. Fort the KPSS test, the null is stated as $H_0: y_t \sim I(0)$ level (or trend) stationary against the alternative $H_1: y_t \sim I(1)$ difference stationary. The critical values for the ADF- and PP-test at 1% and 5% significance level denoted as *** and ** respectively are: (i) constant and trend:-3.98 and -3.42; and (ii) constant only:-3.44 and -2.87. Similarly the critical values for the KPSS tests are: (i) constant and trend: 0.216 and 0.146; and (ii) constant only: 0.739 and 0.463 at the 1% and 5% significant level respectively.

Next, it is necessary to first determine if the data are characterized by nonlinearities by performing a nonlinear dependence test on the data known as the Brock-Dechert-Scheinkman (BDS) test (Brock *et al*. 1987). The test examines the time series for deviations from identically and independently distributed behaviour as well as numerous other purposes including linear and nonlinear dependence using a series of embedding dimensions (m) that is set from a specific range of the standard deviation of the data. Table 4 below depicts the results of the BDS-test. Overall, the null is rejected in most cases suggesting a nonlinear model except for d_3 and d_4 wavelet decomposed data for the nominal exchange rate and only d_3 wavelet decomposed data of the interest rate differential variable, which indicates a linear model would be appropriate to describe the relationship of these variables.

Table 3: Trace Statistic for Johansen Cointegration Test.

	$ln(NER, NIRD)$	$s_4(NER, NIRD)$
$r =$ 0	15.49***	18.55***
$r = 1$	3.84	3.14

Note: r is the number of cointegrating equations and the null is specified as H_0: no cointegrating vector ($r = 0$) against the alternative of at most one cointegrating vector ($r = 1$). ***, **, and * indicate the significance at the 1%, 5% and 10% level respectively.

Table 4: Brock-Dechert-Scheinkman Test for Nonlinear Dependence

(m)	Nominal Exchange Rate						Interest Rate Differential					
	$\ln NER$	d_1NER	d_2NER	d_3NER	d_4NER	s_4NER	$\ln NIRD$	d_1NIRD	d_2NIRD	d_3NIRD	d_4NIRD	s_4NIRD
2	199.58***	2.14***	2.06**	1.32	-1.84*	25.36***	110.54***	3.86***	5.44**	0.56	-0.25	-0.64
3	307.19***	1.82*	1.84*	0.86	0.38	31.66***	167.00***	4.45***	5.68***	0.89	2.33**	-2.65***
4	499.61***	2.45**	2.86***	0.66	0.53	40.42***	267.38***	5.10***	5.77***	0.90	4.31***	-3.34***
5	869.85***	2.71***	2.61***	0.23	-0.62	59.30***	454.39***	5.59***	5.92***	0.65	10.05***	-1.83*

Note: The null for the BDS-test is H_0: identical independent distribution while the dimension ϵ is set to 0.7 the standard deviation of the data as specified in Zivot and Wang, 2003. The p-values are indicated in parentheses with ***, **, and * indicate the significance at the 1%, 5% and 10% level respectively.

To verify the bivariate dynamical relationship between the series, linear and nonlinear Granger causality tests (by Diks and Panchenko (2005; 2006)) were performed on the logarithmic as well wavelet decomposed data. Table 5 summarizes the results of the tests. Aligned with the results of the BDS-test, the linear dependence structure of d_3 unveils linear causality for spot exchange rate and nominal interest rate differential at the 8-month period. The null is simultaneously rejected for $d_1$and d_2 across both relationships indicating that there is a feedback relations, while the remaining variables simultaneous accepts the null indicating that the results are inconclusive. This may be caused by nonlinear characteristic of the data that restrict s the linear Granger causality test. The results of the nonlinear Granger causality tests are also aligned to the results proposed by the BDS-test. Most data characterized as nonlinear reveal causality between nominal exchange rates and nominal interest rate differential. However, it is interesting to note that the relationship between the variables are reversed at the scaling coefficient $s_4$that corresponds to a 16-month period. The null for d_3 and d_4 are simultaneously not rejected indicating the results are inconclusive which may directly be due to the linear feature of the data as presented by the BDS-test.

Table 5: Results of the Linear and Nonlinear Granger Causality Tests.

		Frequency Bands (Months)				
	ln	d_1	d_2	d_3	d_3	s_4
Linear Granger Causality						
$NER \rightarrow NIRD$	0.02	9.40***	6.85***	5.83***	0.50	2.89
$NER \leftarrow NIRD$	0.18	4.25***	3.03*	0.53	0.03	0.08
Nonlinear Granger Causality						
$NER \rightarrow NIRD$	2.16***	1.85**	1.71**	1.21	-0.22	-0.37
$NIRD \rightarrow NER$	-0.53	0.95	1.20	-0.26	0.60	1.80**

Note: The null hypotheses for both linear and nonlinear Granger causality are the same, specified as $H_0: NER \nrightarrow NIRD$ and $H_0: NIRD \nrightarrow NER$. The p-values are indicated in parentheses with ***, **, and * indicate the significance at the 1%, 5% and 10% level respectively. For all pairs, the relationship was investigated using the VAR representation and the lags are based on the SIC criterion whereas the lags for nonlinear Granger causality is $\ell_x = \ell_y$=1.

Australian Journal of Basic and Applied Sciences, 9(8) Special 2015, Pages: 145-150

Conclusion:

Our results indicate the existence of a fairly robust causal nexus between spot exchange rate and nominal interest rate differential especially during short-term that is the 2-to 4 month period. Interestingly, this relationship is reversed during the long-term especially at the 16-month period. Hence altering the interest rates to stabilize the exchange rate is practical as a long-run solution, while exposure to fluctuations exchange rate may be attuned by regulating the interest rates as determined by the central bank. Based on the results, the use wavelet analysis is exceptionally advantageous due to its ability to handle very irregular and nonlinear data by naturally schematizing important information in the data based on the time-scale domain. An interesting avenue for future research is to determine the nature and source of the nonlinear causal linkages between the variables.

ACKNOWLEDGEMENT

We would like to acknowledge support for this project from Universiti Sains Malaysia (USM Short-term grant 304/PMATHS/6313045).

REFERENCES

Almasri, A., G. Shukur, 2003. An Illustration of the Causality Relation between Government Spending and Revenue using Wavelet Analysis on Finnish Data. Journal of Applied Statistics, 30(5): 571-584.

Cumby, R.E., M. Obstfeld, 1981. A Note on Exchange-Rate Expectations and Nominal Interest Differentials: A Test of the Fisher Hypothesis. The Journal of Finance, 36(3).

Dickey, D.A., W.A. Fuller, 1979. Distribution of the Estimators for Autoregressive Time Series with a Unit Root. Journal of the American Statistical Association, 74(366): 427-431.

Dickey, D.A., W.A. Fuller, 1981. Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root. Econometrica, 49(4): 1057-1072.

Diks, C., V. Panchenko, 2005. A Note on the Hiemstra-Jones Test for Granger Non-causality. Studies in Nonlinear Dynamics and Econometrics, 9(2): 1-7.

Diks, C., V. Panchenko, 2006. A New Statistic and Practical Guidelines for Nonparametric Granger Causality Testing. Journal of Economic Dynamics & Control, 30: 1647-1669.

Engel, C., K.D. West, 2005. Exchange Rates and Fundamentals. Journal of Political Economy, 113(3): 485-517.

Gencay, R., F. Selcuk, B. Whitcher, 2002. An Introduction to Wavelets and Other Filtering Methods in Finance and Economics. San Diego(California): Adademic Press.

Godfrey, L.G., 1988. Misspecification Tests in Econometrics. Cambridge, UK: Cambridge University Press.

Hacker, R.S., H.K. Karlsson, K. Mansson, 2012. The Relationship between Exchange Rates and Interest Rate Differentials: A Wavelet Perspective. The World Economy, 35(9): 1162-1185.

Jarque, C.M., A.K. Bera, 1994. A Test for Normality of Observations and Regression Residuals. International Statistical Review, 55: 163-172.

Johansen, S., 1988. Statistical Analysis of Cointegration Vectors. Journal of Economic Dynamic and Control, 12: 231-254.

Kwiatkowski, D., P.C.B. Phillips, P. Schmidt, Y. Shin, 1992. Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root. Journal of Econometrics, 54: 159-178.

Mahajan, A., A.J. Wagner, 1999. Nonlinear Dynamics in Foreign Exchange Rates. Global Finance Journal, 10(1): 1-23.

Mallat, S., 1989. A Theory of Multiresolution Signal Decomposition: The Wavelet Representation. IEEE Transactions on Pattern Analysis and Machine Intelligence, 11: 674-693.

Nakagawa, H., 2002. Real Exchange Rates and Real Interest Differentials: Implications of Nonlinear Adjustment in Real Exchange Rates. Journal of Monetary Economics, 49: 629-649.

Phillips, P.C.B., P. Perron, 1988. Testing for a Unit Root in Time Series Regression. Biometrika, 75(2): 335-346.

Zivot, E., J. Wang, 2006. Modelling Financial Time Series with S-PLUS. 2nd ed. New York: Springer.