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Long memory features and relationship stability of Asia-Pacific currencies against USD

Amirdha Vasani Sankarkumar[1], Murugesan Selvam[1], Balasundram Maniam[2], Marxia Oli Sigo[1]

[1] Department of Commerce and Financial Studies, Bharathidasan University, India
[2] Sam Houston State University, USA

corresponding e-mail: drmselvam[at]yahoo(dot)co(dot)in
address: Dr. Murugesan Selvam, Department of Commerce and Financial Studies, Bharathidasan University, Tiruchirappalli, Tamil Nadu, India - 620024

Abstract: This research study examines the behavior of currency rate, long memory features, and long-term stability in the returns of thirteen Asia-Pacific currencies (AUD, CNY, HKD, INR, IDR, JPY, KRW, MYR, NZD, PHP, SGD, TWD, and THB) against USD over a period of fourteen years (from 2nd January 2001 to 10th December 2014). The study uses descriptive statistics, ADF and PP test, Hurst exponent co-integration model, and figures to investigate the normality, stationarity, long memory features, and long-term relationship stability of sample currencies against USD. This study determined the values of the Hurst Exponent for the first window with 1,000 observations and the second window with 2,500 observations. This study provides significant evidence for the presence of long memory features and relationship stability. The findings of this study would help investors, exchange rate trade policy makers, exporters, and importers to make decisions on the investment, export, and import of goods and services.

JEL Classifications: C58, F31, G14, H21, N25

Keywords: Hurst exponent, long memory features, efficient market hypothesis, Asia Pacific foreign exchange markets, co-integration

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1. Introduction

A widely accepted definition of market efficiency was originally developed by Fama (1970). In an efficient market, prices do fully reflect all available information relevant for the pricing process (Fama, 1970), and none of the market players can earn excess profits by exploiting the known information set (Jensen, 1978). In short, market efficiency is referred to as an informational efficient market (Fama, 1970). The efficient market hypothesis, therefore, implies that future changes in exchange rates should be unpredictable. Since the return of exchange is not predictable in an efficient currency market, it is impossible for exchange rate traders to earn excess returns by using speculation. Conversely, if the exchange market is inefficient, the exchange rate traders can attempt to profit from their transactions through speculating and predicting the future exchange rate (Cicek, 2014). In addition, in the inefficient currency market, the economic policy makers can have an influence on the exchange rates, such as the volatility of the exchange rates.

Fama (1970) subdivides market efficiency into three categories, in terms of the information that security prices should reflect, namely, "weak", "semi-strong", and "strong" forms. In the weak-form efficiency, the information set only comprises past prices, and prices fully and instantly reflect all available (historical) information. Consequently, the market is said to be weak-form efficient if past prices are useless in predicting future prices, and technical analysis is of no use. In the semi-strong form, the

information set additionally comprises all publicly available information relevant to the pricing process. In addition to the weak-form, the semi-strong form includes information on the fundamentals determining the price - i.e. fundamental analysis - that is useless (Cicek, 2014).

The market is semi-strong efficient if all publicly available information has no predictive power. Finally, the market is strong-form efficient if all information is reflected on prices, including the insider information. Thus, the market is said to be efficient if trading on the basis of insider information cannot yield higher profits, and making even insider information useless.

The issue of foreign exchange market efficiency has been tested by several recent studies, employing the cointegration analysis. Analysis of the foreign exchange market efficiency has adopted a new approach. According to Granger (1986), the spot foreign exchange market may be said to be (informational) efficient if the set of spot rates (or any asset prices) were shown to be not cointegrated. Thus, to test the efficiency of markets, it is needed to show that cointegration does not exist. In other words, if they were cointegrated, there would be market inefficiency since there would be Granger causality, running at least in one direction, and thus one price could be used to forecast the other. The existence of cointegration and an error correction mechanism have been interpreted as evidence of inefficiency in the markets (Copeland, 1991).

The short-run deviations from long-run relationship result in an automatic adjustment process that causes the variables to return to their long-run equilibrium relationship. The error correction term contains information regarding the future movements of one variable based on past prices, and thus the deviations from this long-run relationship can be used in the prediction of future exchange rates (Hakkio & Rush, 1989).

The presence of long memory is an important topic in both theoretical and empirical research because its presence is closely connected with the predictability in the first and/or second moments of the price distribution (Wang & Wu, 2012). Despite extensive research on long memory in international equity markets, the issue remains unresolved, and recent empirical studies have been re-examined for the presence or absence of long memory in returns and volatility (Kiliç, 2004; Vougas, 2004).

2. Review of literature

An attempt has been made to review the earlier studies undertaken in the area of efficiency of the foreign exchange market, and Table 1 presents the review of existing studies.

TABLE 1. SUMMARY OF NOTABLE STUDIES RELATING TO EFFICIENCY OF STOCK / FOREIGN EXCHANGE MARKET

RESEARCHERS AND YEARS	PERIOD OF STUDY	TOOLS USED FOR ANALYSIS	SAMPLE INPUTS	FINDINGS
Cajueiro, D.O. et al. (2004)	From 01/01/1992 to 31/12/2002	Rescaled analysis, AR-GARCH	Daily closing prices for emerging markets Argentina (Merval), Brazil (Bovespa), Chile (IPSA), India (SENSEX), Indonesia (JCI), Malaysia (KLCI), Mexico (IPC Index), Philippines (PSI), Korea (KCI), Taiwan (TWI), Thailand (SET Index), and Japan (Nikkei)	The downward trend on Hurst exponent was found to be average in emerging markets. Brazil was the only country which recorded an upward trend, particularly in capital flows. Developed countries were more efficient than emerging countries.
Inci, A. C. (2006)	From June 1973 to April 1998	Descriptive statistics, unit root test, co-integration,	German Mark, Swiss Franc, Japanese Yen, French Franc, British Pound, Belgian Franc and Italian	The relationship between short and long-term interest rates and currencies were differentials. Negative coefficient was

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RESEARCHERS AND YEARS	PERIOD OF STUDY	TOOLS USED FOR ANALYSIS	SAMPLE INPUTS	FINDINGS
		co-integrating Regression and robustness test	Lira.	significant in the real long-term differentials, but consistent with the Short-term domestic bonds and foreign currencies have a suitable substitute.
Lee, Y. H. (2012)	From 02/01/2003 to 30/12/2009	Filter rule and the ratio of top and bottom of filter size set.	Daily exchange rates of EUR, JPY, and GBP	The findings show that people earned more return by catching buy long / sell short strategies of filter rules without considering transaction cost. The transaction of three foreign exchanges (namely, EUR, JPY, and GBP) was more efficient by considering transaction cost.
Chkili, W. et al. (2012)	From 01/01/1999 to 31/12/2010	Descriptive statistics, unit root test, long memory test, GARCH, and VAR	Daily Prices of Stock market indices; CAC40 index (France), DAX Index (Germany) and FTSE100 index (United Kingdom). Exchange rates; USD/EUR and USD/GBP	The relationship between stock and exchange rate was pivotal to portfolio diversification. The risk of hedging strategies was more important for France and Germany than for the United Kingdom.
Caporale, G. M. et al. (2013)	From 13/05/2010 to 14/05/2010	Fractional differencing parameter	Intraday spot exchange rate of USD/GBP	Extending the data set to longer periods of time produced very similar results at high computational cost.
Gayathri. M. et al. (2013)	From 01/09/2007 to 31/08/2012	Descriptive statistics and Rescaled Range Analysis	Daily returns for ITC Ltd., Reliance Industries Ltd., Infosys ltd., ICICI Ltd., and HDFC Ltd	In India, share price series had long memory features with the existence of fractal structure had been confirmed in the findings of the study. From the result of analysis, the study reveals that four of the samples (Reliance Industries Ltd., Infosys ltd., ICICI Ltd., and HDFC Ltd.,) and remaining one (ITC Ltd.) had no long memory in the daily return of series.
Cicek, M. (2014)	From 05/02/2005 to 26/07/2013	Johansen cointegration method, unit root test	Turkish lira/ USD, Turkish lira/ Euro	Speed of adjustment towards long run was a bit faster in the Turkish Lira/USD foreign exchange market. The comparison of Turkish Lira/Euro with spot rate movements was small proportion of forward rates.
Mensi, W. et al. (2014)	From 13/12/2003 to 31/12/2009	Descriptive Statistics, Unit Root Test, ARFIMA, FIGARCH, Long Memory Tests	Daily Closing Spot values of four exchange rates randomly SAR/USD, SAR/EUR, SAR/GBP and SAR/JPY	Mixed results were found for forecasts. This indicates that none of the specifications of the volatility model was appropriate for analyzing the long memory (LM) dynamics in the Saudi Arabia foreign exchange market.
Kang, S. H. et al. (2014)	From 02/01/1990 to 28/06/2013	Descriptive statistics and unit root test	Nominal Exchange Rate for Australian Dollar (AUD), Japanese Yen (JPY), Korean Won (KRW), New Zealand Dollar (NZD), Singapore Dollar (SGD) and Taiwan Dollar (TWD)	This study investigated time varying long memory features over time to evaluate market efficiency. During the Asian currency crisis, an upward trend was witnessed in Hurst exponent. Due to financial crisis in the recent years, the exchange rate markets became inefficient and predictable.
Huang Z. et al. (2015)	From 01/01/2002 to 31/12/2013	GARCH, HAR GARCH, Autocorrelation	S and P 500 index and NASDAQ 100 index and 27 liquidity traded individual stocks	Multi-period for sample indices was used to forecast the volatility of several return series.

TABLE 1. SUMMARY OF NOTABLE STUDIES RELATING TO EFFICIENCY OF STOCK / FOREIGN EXCHANGE MARKET

RESEARCHERS AND YEARS	PERIOD OF STUDY	TOOLS USED FOR ANALYSIS	SAMPLE INPUTS	FINDINGS
Gharleghi, B. et al. (2015)	From 1/1985 to 9/2010	Unit root test (ADF and PP), co-integration test and vector error correction model	ASEAN countries (Indonesia, Malaysia, Philippines, Singapore, and Thailand. Brunei Darussalam, Vietnam, Laos and Myanmar and Cambodia)	This study was divided into pre-crisis and post-crisis. The result of unit root test found the existence of each currency in both sample periods. Co-integration test found no co-integration relationship between currencies in pre-crisis period and only three currencies, namely, IDR, SGD and THB, experienced co-integration relationship in post-crisis period.

3. Research objectives and methodology

Objectives of the study

The main objective of the study was to examine the price behavior of currency rate, long memory features, and long-term relationship stability of sample currencies in Asia-Pacific countries against USD.

Hypotheses of the study

The following null hypotheses were framed and tested in this study

- NH_{01}: There is no normality in exchange rate of sample Asia-Pacific currencies against USD during the study period.
- NH_{02}: There is no stationary in exchange rate of sample Asia-Pacific currencies against USD during the study period.
- NH_{03}: There is no long memory features in the sample Asia-Pacific currencies against USD during the study period, and
- NH_{04}: There is no long-term relationship stability in the sample Asia-Pacific currencies against USD during the study period

Data sources and estimation techniques

This study mainly examined the efficiency of Asia-Pacific foreign exchange market, in respect of normality, stationarity, and cointegration stability over time. This study adopted the research design in line with the design used by Kang (2014) and Cajuerio (2004). Daily closing spot of normal exchange rates, collected from the websites like www.oanda.com and www.exchangerates.com, were used for this study. The normal exchange rate refers to the number of units of domestic currency that can purchase a unit of a given foreign currency. A decrease in this variable is termed nominal appreciation of the currency. Sample currencies were selected, as per the classification available, at Bloomberg business website. At the Asia-Pacific foreign exchange markets, there are 13 currencies, which include Australian Dollar (AUD), Chinese Renminbi (CNY), Hongkong Dollar (HKD), Indian Rupee (INR), Indonesian Rupiah (IDR), Japanese Yen (JPY), Korean Won (KRW), Malaysian Ringgit (MYR), New Zealand Dollar (NZD), Philippines Peso (PHP),

Singapore Dollar (SGD), Taiwan Dollar (TWD) and Thailand Bhatt (THB). The values of all sample currencies (data series) are expressed vis-a-vis the US Dollar and in natural logarithms. The currency of USD was used for the rest of the world because it is the most widely used reserve currency.

The sample period covered 14 years, from 2nd January 2001 to 10th December 2014. Further, to identify the long memory features (Hurst exponent approach), the exchange rates of sample currencies were divided into two parts: First window period and Second window period. The first 1,000 observations, for the period from 02/01/2001 to 20/12/2004, were included in the **First window period,** using the rolling approach. Further, the finishing Hurst exponent, for sub-sample windows of next 2,500 observations, was included in the **Second window period**. In total, this study used 3,500 observations, both in First window period and Second window period, for calculating Hurst exponent values.

For the purpose of testing the normality, stationarity, long memory features, and long-term relationship stability of sample currencies against USD, the following tools were used.

- Descriptive statistics (to assess the normality of the sample currencies against USD),
- Unit root test (to test the stationarity of the sample currencies against USD),
- Hurst exponent approach (to analyze the long memory of sample currencies against USD), and
- Johansen co-integration (to examine the long-term relationship stability of sample currencies against USD).

Limitations of the study

This study used only secondary data (i.e., the daily closing values of sample currencies).

This study covered only 13 currencies from Asia-Pacific foreign exchange markets against USD. The limitations associated with statistical tools like descriptive statistics, unit root test, and cointegration were also applicable to this study.

4. Results of long memory features and relationship stability

The aim of this study was to examine the long memory and relationship stability among sample currencies against USD. For this study, the analysis was made as follows:

a. Descriptive statistics for sample currencies of Asia-Pacific foreign exchange market
b. Unit root test for the sample currencies of Asia-Pacific foreign exchange market
c. Time varying effect by using Hurst exponent approach for the sample currencies of Asia-Pacific foreign exchange market
d. Johansen cointegration test for the sample currencies of Asia-Pacific foreign exchange market
e. Dynamics of the exchange rate returns of sample currencies

Descriptive statistics for sample currencies of Asian-Pacific foreign exchange market

Table 2 shows the results of descriptive statistics for the sample currencies of Asia-Pacific exchange markets during the study period from 02/01/2001 to 10/12/2015. The descriptive statistics includes mean, median, maximum, minimum, standard deviation, skewness, kurtosis, Jarque-Bera test, and probability.

TABLE 2. THE RESULT OF DESCRIPTIVE STATISTICS FOR RETURNS OF SAMPLE CURRENCIES AGAINST USD DURING THE STUDY PERIOD FROM 02/01/2001 TO 10/12/2015

CURRENCY	MEAN	MEDIAN	MAXIMUM	MINIMUM	STD. DEV.	SKEWNESS	KURTOSIS	JARQUE-BERA	PROBABILITY
AUD	-0.00008	-0.00029	0.08563	-0.07392	0.00862	0.82276	15.82692	24367.90	0.0001
CNY	-0.00008	-0.00004	0.00876	-0.02061	0.00092	-3.01086	79.58003	859790.20	0.0001
HKD	0.00000	0.00000	0.00272	-0.00487	0.00032	-1.52526	34.02395	141598.00	0.0001
IDR	-0.00019	0.00000	0.09927	-1.00000	0.01852	-44.95706	2431.84100	861000000	0.0001
INR	0.00009	-0.00004	0.04069	-0.03496	0.00457	0.34897	12.36170	12841.06	0.0001
JPY	0.00003	0.00003	0.03369	-0.04287	0.00650	-0.11496	6.25366	1550.21	0.0001
KRW	-0.00001	-0.00014	0.10805	-0.10414	0.00736	0.63583	43.20263	235737.00	0.0001
MYR	-0.00002	0.00000	0.01750	-0.02681	0.00326	-0.20039	9.18191	5591.80	0.0001
NZD	-0.00013	-0.00033	0.05756	-0.05756	0.00873	0.47412	7.81260	3505.77	0.0001
PHP	-0.00060	-0.00004	0.04713	-1.00000	0.02433	-39.70310	1630.44800	387000000	0.0001
SGD	-0.00007	-0.00011	0.02715	-0.02197	0.00333	0.16170	8.40478	4271.62	0.0001
TWD	-0.00001	0.00000	0.01642	-0.02231	0.00269	-0.03593	8.94670	5153.47	0.0001
THB	-0.00007	-0.00005	0.06166	-0.05135	0.00412	0.90654	34.74208	147288.80	0.0001

Source: Collected from www.oanda.com and computed using E-views.

It is clear from the Table 2 that out of the thirteen sample currencies only one sample currency, namely the Indian Rupee (INR), provided a high mean value of 0.00009 during the study period. It is worthy of note that a positive sign indicates that the currency earned high return; the negative sign indicates that the currency earned low return. The analysis shows that, out of thirteen currencies selected for this study, only two sample currencies, viz Philippines Peso (PHP) and Indonesian Rupiah (IDR), recorded the lowest daily mean returns. In terms of predictability (risk), as measured by the standard deviation of daily currency returns, Philippines Peso earned the highest risk than other sample currencies during the study period. The analysis of skewness vividly shows that the values of skewness for seven sample countries were positive and six sample countries were negative.

According to the results as displayed in Table 2, the sample currencies of Asia-Pacific foreign exchange markets gained a value of kurtosis, which was lower than three or low level, flat top near the mean rather than sharp peak. The analyses of Jarque-Bera values indicate that the returns of all the sample currencies were normally distributed. In short, the distribution of return for all the sample currencies was normal. Similarly, the analysis of the values of skewness, kurtosis, and Jarque-Bera test clearly reveal that the return series for all sample currencies were normally distributed. This implies that the exchange rate returns followed a true random walk process. Hence, the **null hypothesis ($NH0_1$),** namely **"There is no normality in exchange rate of sample Asia-Pacific foreign exchange market against USD during the study period"**, is rejected. Among the 13 sample currencies considered for this study, only one currency, viz INR, recorded a high mean value at 0.00009 against USD. In light of the analysis, it is suggested that the goods traders may export goods and services to India, which may provide higher profit than exporting goods and services to other countries. Besides, the currencies traders may take note of current economic scenarios in different countries and change their trading strategies to earn better returns.

The unit root test for the sample currencies of Asia-Pacific foreign exchange market

The results of the unit root test (Augmented Dickey Fuller Test - ADF, Philips-Perron Test - PP) for daily exchange rate return, in respect to sample currencies, during the period from 02/01/2001 to 10/12/2014, are given in Table 3. The test critical values for

all sample currencies of the Asia-Pacific Foreign Exchange Markets were analyzed at three significant levels of 1%, 5% and 10%.

TABLE 3.THE RESULTS OF UNIT ROOT TEST FOR SAMPLE CURRENCIES AGAINST USD FROM 02/01/2001 TO 10/12/2014

Sample currencies		Unit root test tools					
		ADF test			PP test		
		Statistical value	Critical value	P - value	Statistical value	Critical value	P - value
Australian Dollar against USD	1%	-61.6265	-3.43203	0.0001	-61.6169	-3.43203	0.0001
	5%	-61.6265	-2.86217	0.0001	-61.6169	-2.86217	0.0001
	10%	-61.6265	-2.56715	0.0001	-61.6169	-2.56715	0.0001
Chinese Renminbi against USD	1%	-64.0145	-3.43203	0.0001	-63.8229	-3.43203	0.0000
	5%	-64.0145	-2.86217	0.0001	-63.8229	-2.86217	0.0000
	10%	-64.0145	-2.56715	0.0001	-63.8229	-2.56715	0.0000
Hong Kong Dollar against USD	1%	-60.1822	-3.43203	0.0001	-60.2257	-3.43203	1.0000
	5%	-60.1822	-2.86217	0.0001	-60.2257	-2.86217	1.0000
	10%	-60.1822	-2.56715	0.0001	-60.2257	-2.56715	1.0000
Indian Rupee against USD	1%	-45.0553	-3.43203	0.0001	-59.5810	-3.43203	0.0001
	5%	-45.0553	-2.86217	0.0001	-59.5810	-2.86217	0.0001
	10%	-45.0553	-2.56715	0.0001	-59.5810	-2.56715	0.0001
Indonesian Rupiah against USD	1%	-26.6491	-3.43203	0.0000	-23.4802	-3.43203	0.0000
	5%	-26.6491	-2.86217	0.0000	-23.4802	-2.86217	0.0000
	10%	-26.6491	-2.56715	0.0000	-23.4802	-2.56715	0.0000
Japanese Yen against USD	1%	-60.7440	-3.43203	0.0001	-60.7700	-3.43203	0.0001
	5%	-60.7440	-2.86217	0.0001	-60.7700	-2.86217	0.0001
	10%	-60.7440	-2.56715	0.0001	-60.7700	-2.56715	0.0001
Korean Won against USD	1%	-15.8176	-3.43204	0.0000	-58.8445	-3.43203	0.0001
	5%	-15. 8176	-2.86217	0.0000	-58.8445	-2.86217	0.0001
	10%	-15. 8176	-2.56715	0.0000	-58.8445	-2.56715	0.0001
Malaysian Ringgit against USD	1%	-58.9877	-3.43203	0.0001	-58.9878	-3.43203	0.0001
	5%	-58.9877	-2.86217	0.0001	-58.9878	-2.86217	0.0001
	10%	-58.9877	-2.56715	0.0001	-58.9878	-2.56715	0.0001
New Zealand Dollar against USD	1%	-58.2042	-3.43203	0.0001	-58.2046	-3.43203	0.0001
	5%	-58.2042	-2.86217	0.0001	-58.2046	-2.86217	0.0001
	10%	-58.2042	-2.56715	0.0001	-58.2046	-2.56715	0.0001
Philippines Peso against USD	1%	-9.6921	-3.43203	0.0000	-9.6921	-3.43203	0.0000
	5%	-9.6921	-2.86217	0.0000	-9.6921	-2.86217	0.0000
	10%	-9.6921	-2.56715	0.0000	-9.6921	-2.56715	0.0000
Singapore Dollar against USD	1%	-59.9559	-3.43203	0.0001	-59.9655	-3.43203	0.0001
	5%	-59.9559	-2.86217	0.0001	-59.9655	-2.86217	0.0001
	10%	-59.9559	-2.56715	0.0001	-59.9655	-2.56715	0.0001
Taiwan Dollar against USD	1%	-59.2777	-3.43203	0.0001	-59.9202	-3.43203	0.0001
	5%	-59.2777	-2.86217	0.0001	-59.9202	-2.86217	0.0001
	10%	-59.2777	-2.56715	0.0001	-59.9202	-2.56715	0.0001
Thailand Bhatt against USD	1%	-60.8224	-3.43203	0.0001	-60.8016	-3.43203	0.0001
	5%	-60.8224	-2.86217	0.0001	-60.8016	-2.86217	0.0001
	10%	-60.8224	-2.56715	0.0001	-60.8016	-2.56715	0.0001

Source: Collected from www.oanda.com and computed using E-views.

According to the results of Table 3, which include the results of the unit root test, the probability value of sample currencies was at zero during the study period. From Table 3, ADF test and PP test were found whether data had stationarity or not. The statistical values of both ADF test and PP test for sample currencies (AUD, CNY, HKD, INR, IDR, JPY, KRW. MYR, NZD, PHP, SGD, TWD, and THB) were less than critical values. Also, it is worthy that the values for all the sample currencies were less than that of

test critical values at 1%, 5%, and 10% levels of significance. This reveals the fact that the returns of data, for all sample currencies, attained stationarity during the study period. Based on the analysis of unit root test, it is also further confirmed that the returns from exchange rate for sample currencies attained stationarity during the period of study. Hence, **the Null Hypothesis (NH_{02}),** namely **"There is no stationarity in exchange rate of sample Asia-Pacific foreign exchange market against USD during the study period",** is rejected. The results would help the stakeholders, including the currency traders, to understand and forecast the exchange rate for investing their hard-earned money intelligently and for trading their goods and services by exporting / importing to/from different countries.

Time varying effect by using Hurst Exponent Approach for the sample currencies of Asia-Pacific foreign exchange market

Hurst (1951) developed the re-scaled range statistic (*R* / *S* statistic), observing many natural time series that followed a biased random walk or a special pattern that could be measured by using an exponent, now referred to as the Hurst Exponent. The *R* / *S* statistic is built on a range of partial sums of deviations of a time series from its mean, re-scaled by its standard deviation.

TABLE 4. THE RESULTS OF TIME-VARYING HURST EXPONENTS FOR SAMPLE CURRENCIES AGAINST USD DURING THE STUDY PERIOD FROM 02/01/2001 TO 10/12/2014

Currency	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Probability
FIRST WINDOW PERIOD: TIME VARYING HURST EXPONENTS FOR RETURNS (1000 OBSERVATIONS)									
AUD	-0.00029	-0.00029	0.03703	-0.02460	0.00744	0.48949	4.62626	149.98	0.0001
CNY	0.00000	0.00000	0.00137	-0.00106	0.00025	0.16331	3.61728	20.30	0.0001
HKD	0.00000	0.00000	0.00272	-0.00487	0.00032	-3.88185	83.40179	271591.60	0.0001
IDR	-0.00098	-0.00003	0.09927	-1.00000	0.03320	-27.28834	822.57540	28083654.0	0.0001
INR	-0.00006	-0.00006	0.00892	-0.01524	0.00185	-0.99148	16.24424	7465.10800	0.0001
JPY	-0.00007	-0.00008	0.02501	-0.02881	0.00615	-0.09674	3.99901	43.10088	0.0001
KRW	-0.00017	-0.00024	0.02523	-0.01504	0.00494	0.68061	5.60656	359.93420	0.0001
MYR	0.00000	0.00000	0.00938	-0.00918	0.00043	0.62326	435.67330	7792523.0	0.0001
NZD	-0.00045	-0.00052	0.03083	-0.02502	0.00758	0.54858	4.61203	158.27570	0.0001
PHP	0.00013	0.00006	0.04713	-0.11766	0.00549	-9.03957	225.71360	2078262.0	0.0001
SGD	-0.00005	-0.00006	0.01427	-0.01676	0.00287	0.08719	5.83025	334.69580	0.0001
THB	-0.00010	-0.00007	0.02612	-0.00985	0.00305	1.21549	12.33669	3874.59900	0.0001
TWD	-0.00002	-0.00003	0.01642	-0.01053	0.00230	0.82174	10.31799	2345.46700	0.0001
SECOND WINDOW PERIOD: TIME VARYING HURST EXPONENTS FOR RETURNS (2,500 OBSERVATIONS)									
AUD	0.00000	-0.00030	0.08563	-0.07392	0.00904	0.87838	17.39119	21877.54	0.0001
CNY	-0.00012	-0.00007	0.00876	-0.02061	0.00108	-2.55269	59.34304	333129.50	0.0001
HKD	0.00000	0.00000	0.00252	-0.00250	0.00032	-0.58694	14.38607	13637.06	0.0001
IDR	0.00013	0.00002	0.07479	-0.05855	0.00627	0.96647	19.44378	28532.81	0.0001
INR	0.00016	0.00001	0.04069	-0.03496	0.00528	0.30300	9.60724	4582.05	0.0001
JPY	0.00008	0.00006	0.03369	-0.04287	0.00663	-0.12325	6.88464	1576.99	0.0001
KRW	0.00005	-0.00008	0.10805	-0.10414	0.00812	0.58529	40.34857	145330.10	0.0001
MYR	-0.00003	-0.00003	0.01750	-0.02681	0.00384	-0.16414	6.59610	1357.22	0.0001
NZD	0.00000	-0.00023	0.05756	-0.05756	0.00915	0.43901	8.19101	2884.93	0.0001
PHP	-0.00089	-0.00011	0.01968	-1.00000	0.02857	-34.26383	1198.58000	149000000.0	0.0001
SGD	-0.00008	-0.00016	0.02715	-0.02197	0.00350	0.17884	8.61007	3289.11	0.0001
THB	-0.00006	-0.00003	0.06166	-0.05135	0.00448	0.83176	33.80686	99069.66	0.0001
TWD	-0.00001	0.00000	0.01546	-0.02231	0.00284	-0.21868	8.40330	3058.69	0.0001

Source: Collected from www.oanda.com and computed using E-views.

By performing the least-squares regression, with log (*R* / *S*) *n* as the dependent variable and log (*n*) as the independent one, the slope of the regression was found. This is an estimate of the Hurst Exponent (*H*). The *R* / *S* statistic can classify a time series into a random or non-random process, according to the estimated value of the Hurst Exponent. For instance, if the value of *H* for a time series is 0.5, it indicates that the time series follows a random walk process, that is, an independent process. For a time, series with a long memory process, *H* lies between 0.5 and 1, and this property of a time series provides the predictability of a time series because it shows a trend. If *H* lies between 0 and 0.5, it indicates that the time series possesses an anti-persistent process or negative autocorrelation (Jin & Frechette, 2004). Furthermore, using the time-varying rolling approach proposed by Cajueiro & Tabak (2004) and Cajueiro & Tabak (2005), the values of the Hurst Exponent were estimated. As pointed out earlier, this study estimated the initial Hurst Exponent, for the sub-sample windows of the first 1,000 observations in first window period, using the rolling approach to find the long memory features of Asia-Pacific Foreign Exchange Market for the period from 02/01/2001 to 20/12/2004 **(Panel - A)**. The finishing Hurst Exponent, for sub-sample windows of the next 2,500 observations in Second window period, also used the rolling approach to find the long memory features of Asia-Pacific Foreign Exchange Market, for the period from 21/12/2004 to 10/12/2014 **(Panel - B)**. In total, this study used 3,500 observations, both in First window period and Second window period, for calculating Hurst Exponent values.

Table 4 shows the results of descriptive statistics of estimated Hurst Exponents, for returns of the first 1000 observations as **panel - A** (first window period) and the next 2,500 observations as **panel - B** (Second window period) of thirteen exchanges. In the First window period of Table 4, it is observed that the mean values of all sample currencies - except CNY, HKD, MYR, and PHP - were negative. In the First Sub Window Period (02/01/2001 to 20/12/2004), one sample currency, namely IDR, earned the highest standard deviation value (0.03320), while another sample currency, viz CNY, recorded the lowest value (0.00025) among the sample currencies, during the first window period. In the second window period of Table 4, out of thirteen sample currencies, the mean values of seven currencies - namely INR (0.00016), IDR (0.00013), JPY (0.00008), KRW (0.00005), AUD (0.00000, NZD (0.00000), and HKD (0.00000) - were positive and the mean values of other six currencies - TWD (-0.00001), MYR (-0.00003), THB (-0.00006), SGD (-0.00008), CNY (-0.00012), and PHP (-0.00089) - were negative during the study period. Regarding the values of standard deviation, one currency - viz PHP (0.02857) - out of thirteen sample currencies earned higher value, while the least value was recorded by HKD (0.00032) during the second window period (21/12/2004 to 10/12/2014). According to the values of skewness, Kurtosis and Jarque-Bera test statistics, Hurst Exponents were not normal. The median of the Hurst Exponent was in the range from 0.00006 to -0.00030, for the first window period, **(Panel - A)** and from 0.00006 to -0.00011 **(Panel - B)** for the second window period. This result clearly indicates that returns under both the first window period (02/01/2001 to 20/12/2004) and the second window period (21/12/2004 to 10/12/2014) exhibited long memory properties. Hence, **the Null Hypothesis (NH_{03}),** namely **"There is no long memory features in the sample Asia-Pacific foreign exchange market currencies against USD during the study period"**, is rejected. According to the analysis of 13 currencies, ,only one currency, namely PHP, had attained high mean value (0.00013) against USD with the first 1,000 observations from 02/01/2001 to 20/12/2004 (first window period). It is suggested from the overall analysis of the study, during the first window period, that the goods traders may export goods and services to Philippines, as it is more profitable than exporting the goods and services to other countries. The analysis of the last 2,500 observations, from 21/12/2004 to 10/12/2014 (second window period), shows that INR recorded high mean value (0.00016) against USD out of 13 currencies taken for this study. Hence, the currency traders may trade with India, which would also give higher returns than other countries.

The Johansen cointegration test for the sample currencies of Asia-Pacific foreign exchange market

The results of the Johansen Cointegration Test for daily exchange rate returns of sample currencies during the period from 02/01/2001 to 10/12/2014 are given in **Table 5**. According to the Johansen Cointegration Test, the values of Trace Statistic were higher than the critical values. This indicates that there was long memory in the samples during the study period.

TABLE 5. THE RESULTS OF COINTEGRATION TEST FOR SAMPLE CURRENCIES AGAINST USD DURING THE STUDY PERIOD

Hypothesized No. of CE(s)	Eigenvalue	Trace statistic	0.05 critical value	Prob.**
None	0.230387	7787.690	385.8532	0.0001
At most 1 *	0.216075	6877.175	334.9837	0.0001
At most 2 *	0.201240	6030.727	285.1425	0.0001
At most 3 *	0.196459	5249.465	239.2354	0.0001
At most 4 *	0.188253	4488.953	197.3709	0.0001
At most 5 *	0.182083	3763.768	159.5297	0.0001
At most 6 *	0.171065	3064.910	125.6154	0.0001
At most 7 *	0.167340	2412.580	95.75366	0.0001
At most 8 *	0.154238	1775.838	69.81889	0.0001
At most 9 *	0.147158	1193.380	47.85613	0.0001
At most 10 *	0.139986	639.9081	29.79707	0.0001
At most 11 *	0.028161	115.5521	15.49471	0.0001
At most 12 *	0.004657	16.23078	3.841466	0.0001

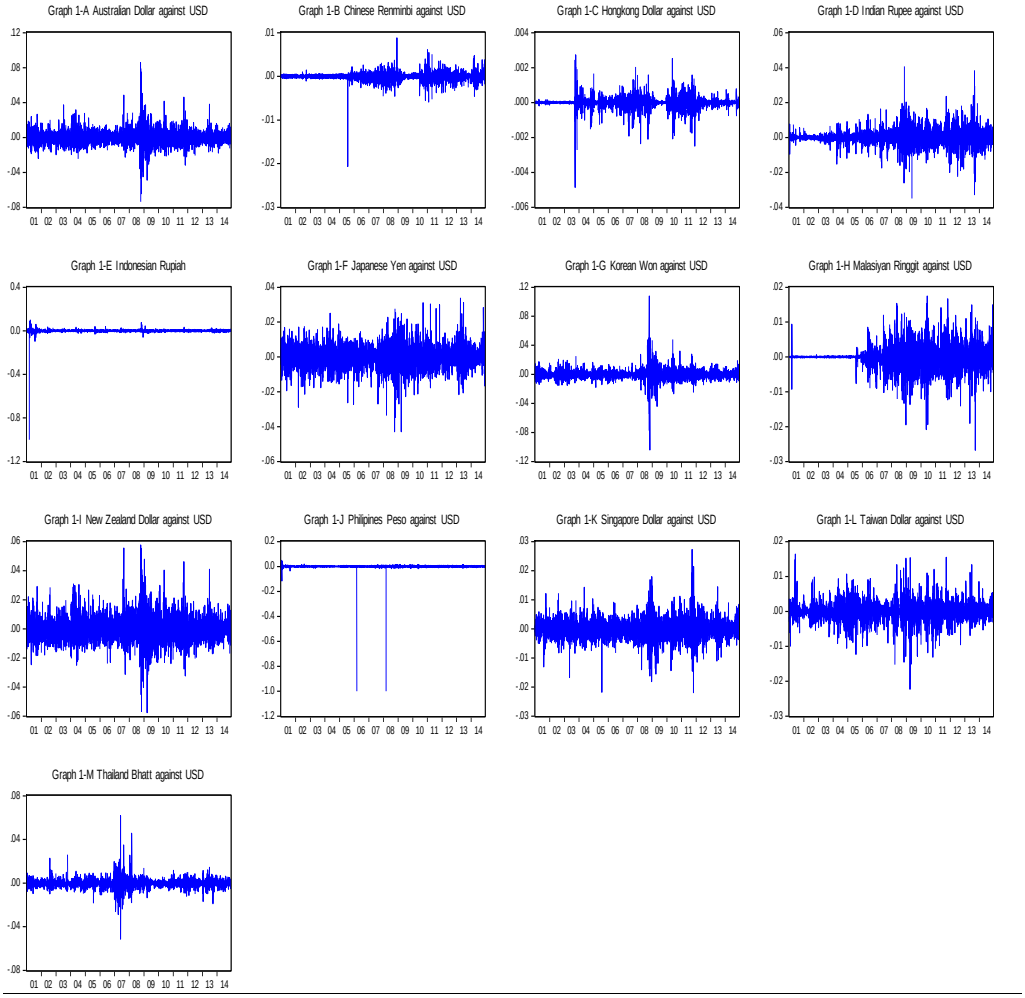
Source: Collected from www.oanda.com and computed using E-views. **MacKinnon-Haug-Michelis (1999) p-values.

The analysis of the Table shows that the values of Trace Statistic CEs were higher than critical values for all CEs at 5% level of significance. This shows that there was cointegration of sample currencies rates during the study period. The results of Johansen Cointegration Test indicate that thirteen currencies considered for this study were integrated, i.e., long-term stable relationship. Hence **the Null Hypothesis (NH_{04}),** namely **"There is no long-term relationship stability in the sample Asia-Pacific foreign exchange market currencies against USD during the study period"**, is rejected. From the overall analysis, it is inferred that there was long memory in respect to sample currencies rates during the short period. This result suggests that the currency traders could confidently invest their hard-earned money to earn better return in the Asia-Pacific foreign exchange market.

Dynamics of the exchange rate returns of sample currencies

Figure 1 shows the dynamics of exchange rates of 13 sample currencies during the study period. The movement of each currency is given in a separate graph (from Graph 1A to Graph 1M). The value of each currency was estimated by using windows of 3,500 observations. The graphs for six sample currencies - namely AUD (Australia), JPY (Japan), MYR (Malaysia), NZD (New Zealand), SGD (Singapore), and TWD (Taiwan) - indicate that there was high volatility, but in the case of HKD (Hongkong), there was no volatility. It is interesting to note that sample currencies like CNY (China), IDR (Indonesia), INR (India), PHP (Philippines) and THB (Thailand) recorded low volatility during the study period.

FIGURE 1. GRAPHS OF EXCHANGE RATE FLUCTUATIONS OF SAMPLE CURRENCIES AGAINST USD DURING THE STUDY PERIOD FROM 02/01/2001 TO 10/12/2014



Conclusion

An attempt was made to study long memory features using the returns of exchange rate of sample currencies in Asia-Pacific foreign exchange market during the study period. The descriptive statistics, unit root test and cointegration were applied to find out long-term memory and relationship stability. The study found that the sample currencies were normally distributed during the study period. This research used ADF and PP Test to judge the logarithmic prices of sample currencies (exchange rate) against USD. This study also applied cointegration to find cointegration relationship and long-term stability relationship among sample currencies against USD. The study found that over time there were long memory features in the returns of sample currencies. This study considered the time - varying effect by using Hurst exponent approach to estimate results for cointegration. The results clearly indicated that there were long memory features for

sample currencies against USD during the study period. Additionally, the dynamics of exchange rate returns showed an upward trend during the 2008 global financial crisis.

The findings of this study differed from the findings of Cajueiro & Tabak (2004), who found in their study that equity markets were becoming efficient over time. At the same time, the results of the study confirmed the findings of Walid Mensi et al. (2014), who concluded that the sample exchange rate recorded long memory, but with little evidence. Copeland (1991) argued that exchange rates could not be cointegrated in an efficient market if the currencies were different assets. Furthermore, Baffes (1994) found that the market efficiency required a cointegration vector that would be consistent with the "no-arbitrage condition". Therefore, this research study proved that the result of Hurst Exponent Approach could identify long memory features, among sample currencies against USD. This research study might benefit investors, policy makers, currency traders, exporters, and importers, when making decisions on their investment by effectively avoiding risk/loss by devising appropriate trading strategies.

Scope for further research

This study mainly focused on the long memory of Asia-Pacific Foreign Exchange Market. The long memory of the Asia-Pacific Foreign Exchange Market was examined for 13 currencies only. In future, a similar study may be carried out by considering some other currencies, in Asia-Pacific Foreign Exchange Market. Further research may focus on the identification of reasons for high, low, and no volatility of sample currencies.

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