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Random walks in asian foreign exchange markets:evidence from new multiple variance ratio tests

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Abstract

This paper revisits the random walk hypothesis for ten Pacific Basin foreign exchange markets. The results suggest that the null hypothesis of random walk is rejected based on the Lo-MacKinlay variance ratio tests, under conditions of both homoskedasticity and heteroskedasticity for the examined series. The use of a battery of new joint variance ratio tests provide further evidence against the random walk behavior than the conventional variance ratio tests. Therefore, we conclude that these Pacific Basin exchange markets violate the random walk hypothesis and are not in line with the weak-form efficient market hypothesis.

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1 Introduction

Testing for the random walk hypothesis (hereafter RWH) in exchange rate has been attracted substantial interest in the empirical finance literature in the past because it provides a benchmark for evaluating the performance of alternative models of exchange rate determination. If the random walk hypothesis cannot be rejected in exchange rate series, then this implies that exchange rate returns or changes cannot be predicted from previous returns. Lo and MacKinaly (1989) pointed out that the random walk hypothesis and weak-form efficiency are equivalent if expected returns are not time-varying.

Three seminal works, i.e., Lo and Mackinlay (1988, 1989) and Poterba and Summers (1988), have provided the foundation for testing for short-term predictability in asset returns. They also suggest that the variance ratio (VR) test is a reliable and more robust methodology to test for predictability than usual unit root tests.[1] A number of researchers has been devoted their efforts to this issue and attempted to apply the variance ratio test to different markets throughout the world. For example, to name a few, Liu and He (1991), Urrutia (1995), Ajayi and Karemera (1996), Fong, Koh and Ouliaris (1997), Pan et al. (1997), Lee et al. (2001), Yilmaz (2003), Belaire-Franch and Opong (2005), Lima and Tabak (2007) and Tabak and Lima (2009). The findings are mixed depending on the different markets, frequency, time period and methodologies employed in the previous studies. For example, Liu and He (1991) applied variance ratio tests based on Lo and MacKinlay (1988) and provided evidence that rejected the RWH for the German mark, Japanese yen and British pound, but failed to do so for the Canadian dollar and French franc vis-á-vis the US dollar. Fong et al. (1997) applied two joint VR tests, Hochberg's (1974, 1988) multiple comparison test (MCT) and Richardson and Smith's (1991) (RS) Wald test, to the same data set of Liu and He. Contrary to the findings of Liu and He (1991), they found that the RS test failed to reject the RWH for all five exchange rates considered, whereas the MCT continued to reject the hypothesis for French franc, German mark and Japanese yen.

The purpose of this paper is to revisit the random walk hypothesis for ten Pacific Basin foreign

[1] Rahman and Saadi (2008), in particular, point out that the unit root tests are not designed to test the random walk hypothesis because they aim at investigating whether a time series is difference-stationary or trend stationary and not, therefore, predictability tests.

exchange markets. We contribute to the literature on pertaining to the testing of the random walk hypothesis by reporting findings based on new joint variance ratio tests, which overcomes the flaws of techniques used in previous studies. As a further contribution, as compared with previous studies where sample ends at the early 2000s, our period of analysis extended to 2008, including the most recent developments in the evolution of the exchange rate.

The remainder of this paper is organized as follows. Section 2 introduces the econometric methodology that we employ, and Section 3 describes the data and the empirical test results. Section 4 presents the conclusions that we draw from this research.

2 Methodology

2.1 The Chow-Denning Test

The Lo and MacKinlay (1988, 1989) test is an individual test where the null hypothesis is tested for an individual value of k. The question as to whether or not a asset return is mean-reverting requires that the null hypothesis hold true for all values of k. However, conducting separate individual tests for a number of k values may be misleading as it tends to over-reject the null hypothesis of a joint test. It may involve much larger Type I error than the nominal level of significance. To avoid this problem, Chow and Denning (1993) devise a joint test with controlled size as follows. Under the null hypothesis $V(k_i) = 1$ for $i = 1, \ldots, l$ against the alternative hypothesis that $V(k_i) \neq 1$ for some i. Chow and Denning's (1993) test statistic is

$$MV_1 = \sqrt{T} \max_{1 \leq i \leq l} \mid M_1(x; k_i) \mid, \tag{1}$$

where $M_1(x; k_i) = (VR(x; k) - 1)\left(\frac{2(2k-1)(k-1)}{3kT}\right)^{-1/2}$ and

$$VR(x; k) = \left\{\frac{1}{Tk}\sum_{t=k}^{T}(x_t + x_{t-1} + \ldots + x_{t-k+1} - k\hat{u})^2\right\} / \left\{\frac{1}{T}\sum_{t=1}^{T}(x_t - \hat{u})^2\right\}$$

with $\hat{u} = T^{-1}\sum_{t=1}^{T} x_t$. This is based on the idea that the decision regarding the null hypothesis can be made based on the maximum absolute value of the individual VR statistics. The statistic follows the studentized maximum modulus distribution with l and T degrees of freedom. Similarly, the heteroskedasticity-robust version of the Chow-Denning test MV_2 can be written as

$$MV_2 = \sqrt{T} \max_{1 \leq i \leq l} \mid M_2(x; k_i) \mid, \tag{2}$$

which is a joint test using $M_2(x,k) = (VR(x;k)-1)\left(\sum_{j=1}^{k-1}\left[\frac{2(k-j)}{k}\right]^2\delta_j\right)^{-1/2}$, and it has the same critical values as MV_1.[2] Chow and Denning's (1993) adjustment controls for the joint test size for the variance-ratio estimates and thus avoids an inappropriately large probability of returning a type I error.

2.2 Whang-Kim Subsampling Test

The Whang-Kim test uses the subsampling technique of Politis, Romano, and Wolf (1997), which is a data-intensive method of approximating the sampling distribution. The Monte Carlo experiment results reported in Whang and Kim (2003) confirm that their new VR test shows excellent power in small samples, coupled with little or no serious size distortions.

To test the null hypothesis that $V(k_i) = 1 (i = 1, \ldots, l)$, Whang and Kim (2003) consider the statistic

$$MV_3 = \sqrt{T} g_T(x_1, \ldots, x_T), \tag{3}$$

where $g_t(x_1 \ldots x_T) = max_{1 \leq i \leq l} \mid (VR(x;k_i) - 1) \mid$ and $VR(x;k)$ is as defined in (1). The sampling distribution function for the MV_3 statistic is written as

$$G_T(x) = P\big(\sqrt{T} g_T(x_1, \ldots, x_T) \leq x\big). \tag{4}$$

Since the distribution function given in (4) is unknown and analytically intractable, Whang and Kim (2003) use the following approximation. Consider a subsample $(x_t, \ldots, x_{t-b+1})$ of size b for $t = 1, \ldots, T - b + 1$. The statistic MV_3 calculated from the subsample is denoted as $g_{T,b,t} = g_b(x_t, \ldots, x_{t-b+1})$. Then, $G_T(x)$ is approximated by the distribution function obtained by the collection of $g'_{T,b,t}s$ calculated from all individual subsamples. It can be written as

$$\hat{G}_{T,b}(x) = (T - b + 2)^{-1} \sum_{t=0}^{T-b+1} 1(\sqrt{b} g_{T,b,t} \leq x),$$

where 1(.) is the indicator function that takes 1 if the condition inside the bracket is satisfied and 0 otherwise.

The $100(1-\alpha)\%$ critical value for the test can be calculated as the $(1-\alpha)th$ percentile of $\hat{G}_{b,T}$, while the p-value of the test is estimated as $1 - \hat{G}_{T,b}(MV_3)$. The null hypothesis that $V(k_i) =$

[2]The critical values of the test are tabulated in Hahn and Hendrickson (1971) and Stoline and Ury (1979).

$1(i = 1, \ldots, l)$ is rejected at the level of significance α if the observed MV_3 is greater than this critical value or if the p-value is less than α. To implement the subsampling technique, a choice of block length b should be made. Whang and Kim (2003) recommend that a number of block lengths from an equally spaced grid in the interval of $[2.5T^{0.3}, 3.5T^{0.6}]$ be taken. However, they find that the size and power properties of their test are not sensitive to the choice of block length.

2.3 Wild Bootstrap test

Kim (2006) proposes the wild bootstrap for the Chow-Denning test given in Eq. (1) and Eq. (2) as an alternative. It is a resampling method that approximates the sampling distribution of a test statistic, and is applicable to data with unknown forms of conditional and unconditional heteroscedasticity (see Mammen, 1993). The wild bootstrap for the Chow-Denning test given in Eq. (1) and Eq. (2) can be conducted in three stages as below:

(i) Form a bootstrap sample of T observations $x_t^* = \eta_t x_t$ $(t = 1, ..., T)$ where η_t is a random sequence with zero mean and unit variance.

(ii) Calculate MV^*, which is the MV statistic in Eq. (1) or Eq. (2) obtained from the bootstrap sample generated in stage (i).

(iii) Repeat (i) and (ii) sufficiently many, say m, times to form a bootstrap distribution of the test statistic $MV^*(j)_{j=1}^m$.

The bootstrap distribution $MV^*(j)_{j=1}^m$ is used to approximate the sampling distribution of the MV statistic. The p-value of the test is estimated as the proportion of $MV^*(j)_{j=1}^m$ greater than the MV statistic calculated from the original data. Under Assumption H* of Lo and MacKinlay (1988), MV^* has the same limiting distribution as MV given in Eq. (1) and Eq. (2). Kim and Shamsuddim (2008) show that the JS and MV^* tests are good alternatives in testing martingale property of a financial time series based on the Morte Carlo evidence. Kim (2006) also stresses that the wild bootstrap tests should be routinely used in practice.

3 Data and Results

The data used in this paper consist of weekly exchange rates from January 8, 1998 to July 30, 2008 for the Australian Dollar (AUD), the Hong Kong Dollar (HKD), the Indonesian Rupiah (IDR), the Malaysian Ringgit (MYR), the New Zealand Dollar (NZD), the Philippine Peso (PHP), the Singapore Dollar (SGD), the South Korean Won (KRW), the Taiwan New Dollar (TWD) and the Thailand Bhat (THB) because these Pacific Basin economies have exhibited phenomenal growth throughout most of the past two decades. Lo and MacKinlay (1988) stated that weekly sampling is the ideal compromise, yielding a large number of observations while minimizing the biases inherent in daily price data.[3] For each week, the exchange rate is observed on Wednesday, or the next trading day if the markets are closed on Wednesday. The returns were constructed as the first differences of the log exchange rates. The data set is obtained from the Pacific Exchange Rate Service at `http://fx.sauder.ubc.ca/`.

Table 1 shows the sample statistics for the changes of foreign exchange rates. The skewness of the return series is positive for the AUD, IDR and NZD but negative for all the others. The negative skewness implies that exchange rate returns are flatter to the left compared to the normal distribution. The coefficients of skewness reveal non-normality in the data. The excess kurtosis in all cases is much higher than 0, which indicates that the empirical distributions of the foreign exchange returns have fat tails. The Jarque-Bera statistics confirm the significant non-normality in the ten Pacific Rim markets. The Ljung-Box Q-statistics, LB(24), for the raw returns indicate significant autocorrelations for all foreign exchange returns. We also report a standard ARCH test for the filtered residuals. The test results indicate significant ARCH effects for eight of ten markets with exceptions of Australia dollar and New Zealand dollar.

Preliminary results show that the signs of the Lo-MacKinlay variance ratio test, under the maintained hypothesis of homoscedasticity, suggest a positive dependence in most of the exchange rate return series examined, indicating a strong rejection of random walk hypothesis. The rejections are robust under the maintained hypothesis of heteroscedasticity in most of the exchange series, suggesting that any rejection of the hypothesis of random walk behavior of the

[3]Lo and MacKinlay (1988) argued that while daily sampling yields many observations, the biases associated with non-trading, the bid-ask spread, asynchronous prices, etc., are troublesome.

series examined could be due to serial correlations rather than to heteroskedasticity.[4]

Table 2 reports the results from a battery of joint VR tests. Results from the Chow-Denning MV_1 test suggest that the null hypothesis of random walk is rejected at the 5% level for all of the Pacific Basin exchange rate returns. However, results from the heteroskedasticity consistent variance ratio test given by MV_2 show that the null cannot be rejected for the cases of HKD, IDR, MYR, PHP and THB, indicating that rejections of null hypothesis of random walk behavior of these series examined could be due to heteroskedasticity.

The results from previous statistics proposed to test the RWH so far have an asymptotically standard normal distribution. Nonetheless, statistical inference based on the asymptotic distribution could be misleading in finite samples. The Whang and Kim (2003) subsampling test and Kim's (2006) wild bootstrap procedure for the Chow-Denning VR tests are considered here to generate better properties than the conventional VR tests when the sample size is relative small. Results from the data-intensive method of the Whang-Kim subsampling test, again, are not in favor of the null hypothesis of random walk for all cases. Finally, the Kim's wild bootstrapping tests (MV^*) show the results that the null hypothesis of random walk for most of the exchange rate returns is rejected at the 5% significance level with the exceptions IDR, MYR and PHP.

It is interesting to compare our empirical results to some relevant studies. For example, Ajayi and Karemera (1996) applied Lo-MacKinlay variance ratio test to Asian daily and weekly exchange rates from January 1, 1986 to December 12, 1991. Lee et al. (2001) applied the joint variance ratio test to Pacific Basin daily exchange rates from January 4, 1988 to December 29, 1995. Their joint ratio test results show that there is little evidence of serial correlations in the daily exchange rate series with the exception of Korea. Lima and Tabak (2007) provided empirical evidence to favor the null hypothesis of random walk for Indonesia, the Philippines, Malaysia, South Korea and Thailand. Our results are, in general, consistent with those reported in Ajayi and Karemera (1996) but are inconsistent with those reported in Lee et al. (2001) and Lim and Tabak (2007). The obvious problem in reconciling these results is the different sample periods, frequency and methodologies employed by different researchers.

[4]The results are available from the author upon request.

4 Concluding Remarks

This study employs new multiple variance ratio tests to examine the behavior of weekly Pacific Basin foreign exchange markets for 10 countries. Based on the results of a battery of the joint VR statistics, the null hypothesis of random walk is strongly rejected. The rejections of the random walk hypothesis by the variance ratio tests in our study indicate that the weak-form efficient market hypothesis is violated. However, identifying the exact source of the failure of the random walk hypothesis for these markets is beyond the scope of this paper.

In line with Ajayi and Karemera (1996), two interesting economic implications are extracted from our results. First, as suggested in Lo and MacKinlay (1989) and adopted in Liu and He (1991) the use of variance ratio provides a convenient way to differentiate between the overshooting or undershooting phenomena in exchange rates. In this study, most estimates of the variance ratios are larger than unity, suggesting the presence of positive serial correlation in the series. The presence of positive serial correlation in an exchange series has been linked to the phenomenon of exchange rate undershooting, and official intervention in the market. Second, evidence against random walk in exchange rates lends some support to classical monetary models of exchange rates (e.g. Frenkel, 1976; Dornbusch, 1976), which retain the purchasing power parity as a long-run equilibrium condition.

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Table 1: Summary Statistics for Exchange Rate Returns

	AUD	HKD	IDR	MYR	NZD
Mean	−0.071	0.001	0.018	−0.057	−0.046
S.D.	1.244	0.050	3.202	0.778	1.359
SK	0.281	−2.437	1.628	−5.036	0.339
EK	0.330	29.502	30.846	56.797	1.135
JB	9.770**	20527.802**	22088.579**	76390.806**	40.206**
LB(24)	60.100**	76.800**	18.591**	265.537**	40.453**
ARCH(4)	1.499	19.011**	92.928**	74.825**	0.971

	PHP	SGD	KRW	TWD	THB
Mean	−0.000	−0.045	−0.102	−0.018	−0.081
S.D.	0.999	0.605	1.125	0.524	1.145
SK	−1.897	−0.049	−0.676	−0.464	−1.410
EK	20.254	3.084	6.645	6.201	15.202**
JB	9748.858**	218.598**	1055.854**	902.862**	5488.690**
LB(24)	62.434**	81.368**	61.213**	112.107**	101.060**
ARCH (4)	11.861**	32.485**	37.612**	2.272**	47.294**

(1) ** denotes significance at the 5% level.

(2) Mean and S.D. refer to the mean and standard deviation of the returns on each market.

(3) SK is the skewness coefficient.

(4) EK is the excess kurtosis coefficient.

(5) JB is the Jarque-Bera statistic.

(6) LB(24) is the Ljung-Box Q statistic, calculated with twenty-four lags, for raw returns.

(7) ARCH(4) is the ARCH test, calculated with four lags, for residuals from an AR(4) regression on raw returns.

Table 2: Results of Joint Variance Ratio Tests

	AUD	HKD	IDR	MYR	NZD
MV_1	5.527**	6.010**	4.821**	5.299**	5.245**
MV_2	5.509**	1.963	2.174	1.084	5.192**
Whang-Kim Subsampling MV_3 Test (p-value)					
$b = 35$	0.000**	0.000**	0.000**	0.000**	0.011**
$b = 54$	0.000**	0.000**	0.000**	0.000**	0.028**
$b = 73$	0.000**	0.002**	0.000**	0.000**	0.014**
$b = 92$	0.073**	0.023**	0.000**	0.000**	0.000**
$b = 111$	0.070**	0.036**	0.002**	0.000**	0.020**
$b = 130$	0.056*	0.045**	0.026**	0.000**	0.078*
Kim's MV^* Test (p-value)					
	0.000**	0.086*	0.115	0.634	0.000**

	PHP	SGD	KRW	TWD	THB
MV_1	2.626**	6.187**	5.312**	7.789**	5.717**
MV_2	1.579	3.601**	2.642**	6.143**	2.208
Whang-Kim Subsampling MV_3 Test (p-value)					
$b = 35$	0.000**	0.000**	0.000**	0.000**	0.000**
$b = 54$	0.038**	0.000**	0.000**	0.000**	0.048**
$b = 73$	0.054**	0.000**	0.000**	0.000**	0.089*
$b = 92$	0.123	0.000**	0.030**	0.000**	0.121
$b = 111$	0.170	0.000**	0.108	0.000**	0.172
$b = 130$	0.196	0.000**	0.194	0.000**	0.229
Kim's MV^* Test (p-value)					
	0.279	0.001**	0.056*	0.000**	0.041**

The critical values for the MV_i, $i = 1, 2$ statistics at the 10% and 5% significance levels are 2.311 and 2.568, respectively.