Asia-Pacific Journal of Business (아태비즈니스연구)
Vol. 11, No. 1, March 2020 (pp.61-75)
https://doi.org/10.32599/apjb.11.1.202003.61.

APJB
ISSN 2233-5900 (Print)
ISSN 2384-3934 (Online)

A Study on the Efficiency of the Foreign Exchange Markets: Evidence from Korea, Japan and China

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Received 28 February 2020, Revised 18 March 2020, Accepted 25 March 2020

Abstract

Purpose - The purpose of this study was to examine the efficiency of the foreign exchange markets in Korea, Japan and China.

Design/methodology/approach - This study collected 1327 observations each of the daily closing exchange rates of the three currencies against the US dollar for the sample period from January 1, 2015 to January 31, 2020, based on the tests for autocorrelation, unit root tests and GARCH-M(1,1) model estimation.

Findings - We have found that the autocorrelation test indicates the lack of autocorrelation and unit root test confirms the existence of unit roots in all times series of the three currencies, respectively. The GARCH-M(1,1) test results, however, suggest that the exchange rates do not follow a random walk process. In conclusion, the recent spot foreign exchange markets in Korea, Japan and China are believed to be informationally inefficient.

Research implications or Originality - These findings have practical implications for both individual and institutional investors to be able to obtain excess returns on their investments in the foreign exchange markets in three countries by using appropriate risk management, portfolio strategy, technical analysis, etc. This study provides the first empirical examination on the foreign exchange market efficiency in the three biggest economies in Asia including China, which has been excluded from research due to its exchange rate regime.

Keywords: Autocorrelation, Efficient Market Hypothesis, GARCH Model, Random Walk Hypothesis
JEL Classifications: C12, G14

Ⅰ. Introduction

Financial markets are said to be efficient if the current asset prices fully reflect all the available and relevant information. The efficient market hypothesis (EMH) has strong implications for forecasting (Fama, 1991). If foreign exchange markets are efficient, the current exchange rate has already reflected all relevant information, such as money supplies, inflation rates, trade balance, etc. In a weak-form efficient market, particularly, all historical price and volume are reflected in current rates. Old news and trend are already impounded in historical prices and therefore of no help in

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predicting future exchange rate. Since news by definition is unpredictable, the exchange rate will change randomly over time. If the exchange rate indeed follow a random walk, the future exchange rate is predicted to be the same as the current rate.

While a majority of prior literature regarding the test of the random walk and efficiency hypothesis have focused on examination of the behavior of stock markets, an increasing number of studies have been implemented to investigate the efficiency of foreign exchange markets across the world. The foreign exchange market is the largest financial market in the world, with an average of $6.6 trillion daily transactions as of April 2019 (BIS, 2019). This have motivated researchers and market participants, as well as policy-makers, to get interested in whether or not foreign exchange markets are efficient.

In earlier studies such as Darby (1983), Adler and Lehmann (1983), Huizinga (1987), Baillie and Selover (1987) and Taylor (1988), the unit root tests were applied for the examination of the random walk and efficiency in foreign exchange markets in developed countries. All these studies failed to reject the unit root hypothesis for the exchange rate while Coughlin and Koedijk (1990) and Lothian (1990) conducted the random walk test using both the Dickey Fuller and Augmented Dickey-Fuller unit root tests and cointegration tests. Other studies used different tests for the efficiency of foreign exchange market. Jeon Bang-Nam and Seo Byeongseon (2003) investigated whether the Asian financial crisis affected the efficiency of foreign exchange markets in four Asian countries such as Thailand, Indonesia, Malaysia and Korea to find that empirical evidence based on the bivariate and multivariate cointegration estimations using the high-frequency data from January 1996 to February 2001 is mostly consistent with the across-country efficient market hypothesis in the Asian foreign exchange markets. Chen and Leung (2003) developed a new method called Bayesian Vector Error Correction Model to forecast 1 month ahead changes of currency exchange rates for three major Asia Pacific economies and also to compare forecasting performance between the random walk model and the Bayesian Vector Autoregression. Aroskar et al. (2004) used an error correction model, a random walk model and Granger causality to examine the foreign exchange market efficiency around the 1992 European financial market crisis. Sweeney (2006) used the Seemingly Unrelated Regression (SUR) method on panels of the nominal rates of G10 for period of March 1973 to December 1996. Chu and Lu (2006) employed the behavior of dynamic international asset allocation to compete the random walk model for prediction of the monthly exchange rate of the currencies of Japan, Singapore, Taiwan and Germany against the US dollar. Phengpis (2006) used the Johansen cointegration test to investigate foreign exchange market efficiency of Western European countries during the 1992–1993 European currency crisis and several Asian countries during the 1997–1998 Asian currency crisis. The study argued that the cointegration test does not seem to be reliable since the test results do not reveal inefficiency even if foreign exchange markets are truly inefficient during these two crises.

Recently the variance-ratio tests have

been employed for the foreign exchange market efficiency following Liu and He (1991), Smoluk, Vasconcellos and Kramer (1998), Wright (2000), Lee, Pan and Liu (2001) and Chang (2004). Later Oh, Kim and Eom (2007) investigated the degree of randomness in time series of 17 foreign exchange markets in European, North American, African and Asia-Pacific region using the Apron to particularly find that the efficiency of markets with a small liquidity such as Asian foreign markets improved significantly after the Asian financial crisis. Azad (2009) examined the random walk and efficiency hypothesis for 12 Asia-Pacific foreign exchange markets by use of unit root tests and variance ratio tests and found that most of the markets have been efficient. Chiang et al (2010) used the traditional variance ratio test of Lo and MacKinlay (1988, 1989), the non-parametric-based variance ratio test of Wright (2000) and the multiple-variance ratio test of Chow and Denning (1993), to re-examine the validity of the weak form efficient market hypothesis for foreign exchange markets in four floating-rate markets in neighboring Asian economies (Japan, Korea, Taiwan and the Philippines) and concluded that the foreign exchange markets of Japan, Korea and the Philippines are weak form efficient while the foreign exchange market of Taiwan is inefficient. Salisu, Oloko and Oyewole (2016) investigated the foreign exchange market efficiency of nine selected Asia-Pacific countries, including Korea, Japan and China, employing the Wild Bootstrap Automatic Variance Ratio test and Wild Bootstrap Generalized Spectral test. Empirical result from this study shows that FX market efficiency could be inconsistent over time due to changes in policies and events.

In the previous studies for the foreign exchange market efficiency, various methods have been implemented over the different horizons of the target markets. This study aims to examine the market efficiency, focusing on the foreign exchange markets in the top three biggest economies in Asian region, particularly including China, in the framework of the random walk behavior.

A number of studies examined the efficiency of foreign exchange markets in Asia. But studies on Asian foreign market efficiency focused on Korea, Japan or other countries with floating exchange regime, excluding Chinese market because its exchange rate regime was not a floating, or flexible, system. China has its exchange rate regime of crawl-like arrangement[1], which requires the exchange rate to remain within a narrow margin. Recently, however, foreign exchange market in China has been changed to be substantially flexible. From late June 2010, Chinese currency began to float. Only recent years, however, China has been lowering barriers to foreign exchange transaction with the goal of establishing its currency, Yuan, as a major global currency like euro or US dollar. The potential for the Chinese currency to become a global currency is not impossible. According to the BIS report, the trading volume of Korean won, Chinese yuan and Japanese yen against US dollar globally make up 1.9 percent, 4.1 percent and 13.2 percent as of April 2019, respectively. Korean and Chinese currencies slightly gained their

1) A country's exchange rate arrangement is classified by the International Monetary Fund into several separate regimes.

Table 1. Descriptive Statistics for Exchange Rates

	KRW	JPY	CNY
Mean	1138.345	112.2435	6.647502
Median	1134.19	111.31	6.6716
Maximum	1243.13	125.62	7.1789
Minimum	1054.94	99.89	6.1875
Std. Dev.	38.7083	5.465238	0.263105
Skewness	0.066047	0.421802	-0.180865
Kurtosis	2.368997	2.746925	1.914136
Jarque-Bera	22.97996	42.89052	72.42923
Probability	0.00001	0	0
Sum	1510584	148947.2	8821.235
Sum Sq. Dev.	1986788	39606.06	91.79137
Observations	1327	1327	1327

Note: KRW, JPY and CNY represent the exchange rate of Korean won, Japanese yen and Chinese yuan against the US dollar, respectively.

market share, up from 1.5 percent 3.8 percent in 2016 while Japanese yen's share in global turnover dropped to 13.2 percent from its 2016 17.8 percent, still remaining the third most traded currency in the world (BIS, 2019). It would provide meaningful results to examine the efficiency of Chinese foreign exchange market and compare it with those of other two economies.

Daily closing exchange rates of the three currencies against the US dollar are collected over a sample period from January 1, 2015 to January 31, 2020. The research method is based on a step by step and a detailed empirical investigation to testing the requirements of the random walk model for each time series, using conventional econometrics tests of this hypothesis. In particular, we have employed ARCH and GARCH-M(1,1) estimation and testing strategy for exchange rate variations instead of popular variance ratio tests, as it appears that former methods provide more detailed information on the cause and the structure of variations in each time series and its volatility over time. Furthermore, each statistical procedure that is used in this paper should have required level of 'power of a test', given relatively large size of sample used in this investigation.

The rest of the paper is organised as follows. Section 2 describes briefly the data and underlying methodology. Section 3 discusses empirical results and their implications, and finally a conclusion is presented in Section 4.

II. Data and Methodology

1. Data

The data used in this study are daily closing spot exchange rates of Korean won, Japanese yen and Chinese yuan against the

US dollar for the period from January 1, 2015 to January 31, 2020. Traditionally, Chinese exchange rate system has been known as tightly managed one in order for the authority to control the movement of the Chinese currency for their trade purpose. Recently, Chinese foreign exchange market has been changed to be substantially flexible hoping for Yuan, the Chinese currency, to become a global currency. Accordingly, sampling period has been set to be most recent period starting from 2015. The sample is composed of a total of 1327 observations of each exchange rate, which is believed to be sufficient for statistical analysis.

〈Table 1〉 summarizes descriptive statistics for daily closing rates of the currencies of Korea, Japan and China. According to the standard deviations of the data series of the currencies, Korean won is most volatile while Chinese yuan moves within very a limited range, with its smallest standard deviation. The data of Korean and Japanese currencies have a positively skewed distributions with the tail on the right side being longer or fatter. Skewness is a measure of the asymmetry of the observations in a probability distribution. The skewness is zero for a normal distribution. Kurtosis coefficients of the three exchange rates are less than 3, indicating the a platykurtic distributions having thinner tails. The variables used in this study are believed not to be normally distributed as shown by the statistics of Jarque-Bera, Skewness and Kurtusis.

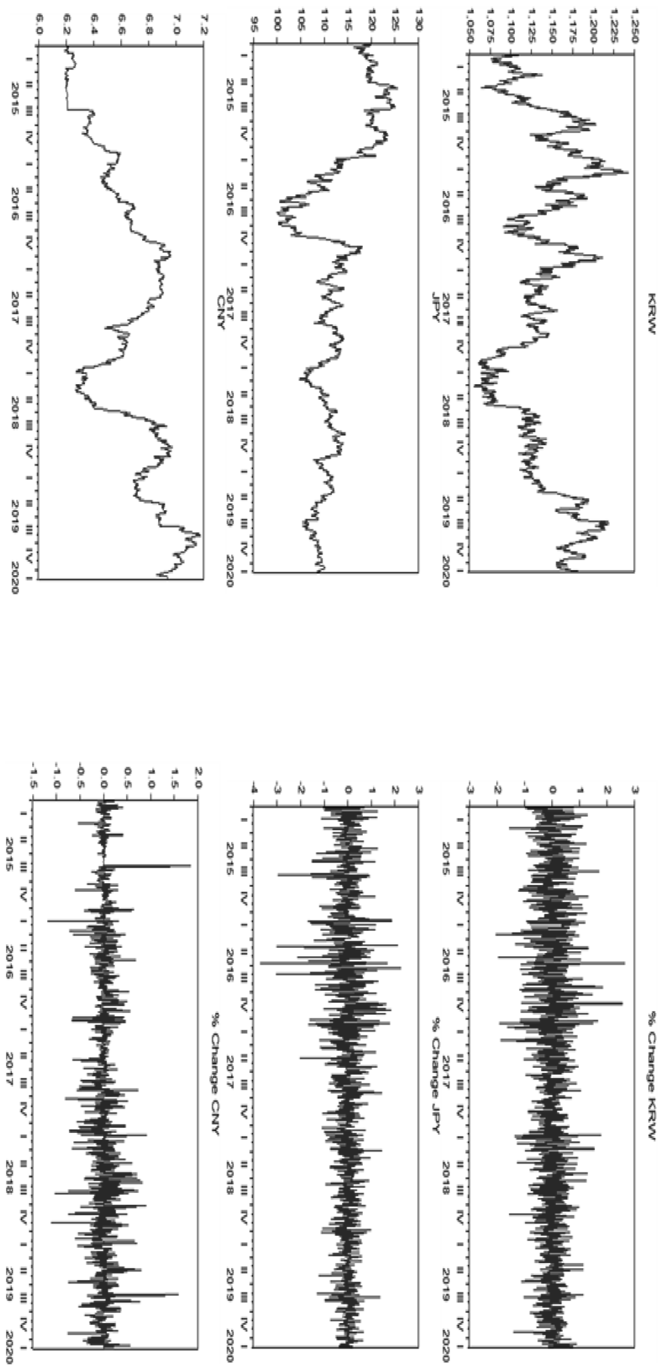
〈Fig. 1〉 shows the movement of exchange rates of the three currencies and their daily percentage return for the period from January 1, 2015 to January 31, 2020. As for the market fluctuation, calculated as daily percentage change of exchange rates in the foreign exchange markets from the previous day, Korean won and Japanese yen was shown to be more volatile than the Chinese yuan, which is confirmed in the above descriptive statistics.

2. Methodology

Earlier existing studies on random walk and market efficiency have employed unit root tests for investigating the efficiency of the financial markets. It is not satisfactory, however, to apply the random walk hypothesis merely by use of the unit root test results. Rahman and Saadi (2007) argued that results of stationarity tests could lead to different conclusions when alternative tests for finding dependence within the residuals terms have been used.

In this empirical investigation, within the random walk model framework, along with the unit root tests, we will be also applying autocorrelation tests as well as ARCH and GARCH-M(1,1) estimation and tests of variance on each time series under examination, following Seddighi and Nian (2004). These procedures are used in practice to inform whether or not the variance of a time series and its volatility change over time. Together, these techniques provide information on financial time series volatility and the way it moves over time. If they are found to be not present in time series relating to a financial market, then the market is extremely fast and efficient in processing financial information and volatility in the market tends to disappear and not to linger on

Fig. 1. Trend for Exchange Rates



overtime. The reverse is also true, that is, if they are found to be present in time series of a market, then the market tends to be sluggish in processing information, generating clusters and time variant volatility, and therefore not efficient in processing information.

The testing procedure follows three processes: (1) the Durbin–Watson test and the Breusch-Godfrey test are used for autocorrelation to test the assumption of the model that the successive occurrences go independently; (2) the Augmented Dickey–Fuller tests are used for unit root to examine the assumption that the occurrences are identically distributed (see, for example, Seddighi (2012)); (3) the ARCH test is used to investigate whether the residuals contain hidden structure and fit a GARCH-M(1,1) model to the first difference if the ARCH effect is found to exist in the data series (see, for example, Bollerslev (1987)).

2.1 Random Walk Model

A market is assumed to be weak-form efficient, the random walk hypothesis, when the current exchange rate reflects all available and relevant information and hence the best predictor of current prices is the past prices. In order to test the market efficiency, a random walk model is defined as follows;

$$P_t = \alpha + \beta P_{t-1} + \mu_t \quad (1)$$

Or, in another form:

$$\Delta P_t = P_t - P_{t-1} = \alpha + (\beta - 1)P_{t-1} + \mu_t \quad (2)$$

where P_t is the price of a currency at time t, P_{t-1} is the price of the currency in the immediately previous period and μ_t is a random error, α and β are constants (parameters) that can be estimated.

When the following requirements are met: (1) μ_t is tested to have zero mean and its values are independent of each other, (2) $\beta = 1$, so that $P_t = \alpha + P_{t-1} + \mu_t$, or, $\Delta Pt = \alpha + \mu_t$. If $\alpha = 0$, there is a random walk without drift, and if $\alpha \neq 0$, there is a random walk with drift. Therefore, the above requirements should be tested in order to test whether the movement of asset prices follows the random walk.

2.2 Autocorrelation Tests

When the residuals in time series are correlated with their own lagged values, it is called the serial correlation, or the autocorrelation. The autocorrelation can be used for detecting non-randomness in data. If no significant autocorrelation is found, the series are believed to follow a random walk process. This study used two methods to test for autocorrelation, the Durbin-Watson (DW) test and the Breusch–Godfrey test.

To overcome the key limitations of the DW test, the Breusch-Godfrey test is also employed. Unlike the DW statistic, the Breusch-Godfrey test, also referred to as the Lagrange Multiplier (LM) test, is useful in testing autocorrelation for higher orders as well as first-order and is applicable whether or not there are lagged dependent variables (Godfrey, 1988). The null hypothesis is that no autocorrelation exists in the residuals up to the specified order. The F-statistic and Obs*R-squared (the number of observations times the R-square) statistic are used. Under the null hypothesis, there is an asymptotic distribution in the Obs*R-squared statistic. The F-statistic is determined according to the comparison of the restricted and

Table 2. Random Walk Model

Variables	At Level	At First Difference	
	Model I Random Walk Model without drift	Model II Random Walk Model with drift	Model III Random Walk Model with trend and drift
Equation	$\Delta P_t = (\beta-1)P_{t-1} + \Sigma\beta_i\Delta P_{t-i} + \mu_t$, $\Sigma\beta_i\Delta P_{t-i}$: augmented lags of dependent variable	$\Delta P_t = \alpha + (\beta-1)P_{t-1} + \Sigma\beta_i\Delta P_{t-i} + \mu_t$ α: drift parameter	$\Delta P_t = \alpha + \rho_t + (\beta-1)P_{t-1} + \Sigma\beta_i\Delta P_{t-i} + \mu_t$ ρ_t: deterministic trend
Procedure	Test β = 1, using ADF distribution. If the null hypothesis is rejected, it is concluded that there are no unit roots. Otherwise, it is concluded that the data series is non-stationary. The critical values of statistic are available from Fuller (1976).	(a) Test β = 1, using ADF distribution. If the null hypothesis is rejected, it is concluded that there are no unit roots. Otherwise, continue on to step (b). (b) Test α = 0 given β = 1, using ADF distribution for Model II. If the null hypothesis is rejected, β = 1 needs to be tested using the normal distribution as follows. Otherwise, go to estimate and test Model I. (c) Test β = 1, using the normal distribution. If the null hypothesis is rejected, it is concluded that there are no unit roots. Otherwise, it is concluded that the data series is non-stationary.	(a) Test β = 1, using ADF distribution. If the null hypothesis is rejected, it is concluded that there are no unit roots. Otherwise, continue on to step (b). (b) Test ρ = 0 given β = 1, using ADF distribution for Model III. If the null hypothesis is rejected, β = 1 needs to be tested using the normal distribution as follows. Otherwise, go to estimate and test Model II. (c) Test β = 1, using the normal distribution. If the null hypothesis is rejected, it is concluded that there are no unit roots. Otherwise, it is concluded that the data series is non-stationary.

Note: This table was made based on Seddighi and Nian (2004).

unrestricted sum of squared residuals.

2.3 Unit Root Tests

Box and Jenkins (1970) state that the nonstationarity is such that differencing will create stationarity. This concept is what is meant by the term integrated: a variable is said to be integrated of order d, written *I(d)*, if it must be differenced d times to be made stationary. Thus, as for the equation $P_t=P_{t-1}+\mu_t$, μ_t is a stationary error term, i.e. *I(0)*. If $|\beta|<1$, then P is I(0), i.e. stationary, but if β = 1, then P is *I(1)* because $\Delta P_t=\mu_t$,which is *I(0)*. Thus formal tests of stationarity are tests for β = 1 and, because of this, are referred to as tests for a unit root. The case of $|\beta|>1$ is ruled out as being unreasonable because it would cause the series P_t to explode.

The equation $\Delta P_t=(\beta-1)P_t-1+\mu_t$, rewritten from $P_t=\beta P_{t-1}+\mu_t$, suggests that if ΔP_t were regressed on P_{t-1} the *t* statistic on the slope coeffient could be used to test β = 1, with sufficiently large negative t-statistic leading to rejection of the unit root null hypothesis. However, problems arise with this general procedure. (1) Under the null hypothesis of a unit root this t-statistic does not have a t-distribution, so that special critical values are required. (2) The special critical values are different depending on what kind of I(1) process is being specified by the null hypothesis (Kennedy, 1996).

The special critical values for the t-statistic from the auxiliary regression have been tabulated for several cases, many of which appear in Fuller (1976) and Dickey and Fuller (1981), and are referred to as DF, or Dickey-Fuller tests. The special t-statistic is known as the -statistic. The ADF, or augmented Dickey-Fuller test (ADF test), which is proposed to accommodate error autocorrelation by adding lagged differences of P_t, is employed in the more general case where the disturbances are serially correlated. The ADF test statistic has the same asymptotic distribution as the DF statistic, so the same critical values can be used. The DF and ADF tests are applied to regressions runs in three forms adopted from Seddighi and Nian (2004), with which the Random Walk Model with trend and drift, with drift, and without drift can be estimated as presented in 〈Table 2〉.

The ADF test seems to be the most popular unit root test, because of its simplicity and also because MonteCarlo studies such as Haug (1993, 1996) have found that it performs well. However, it should be noted that unit root tests, including the ADF test, have limitations:

(1) 1. Because the traditional classical testing methodology accepts the non-stationarity, unless there is strong evidence against it, unit root tests usually conclude that there is a unit root. This problem is exacerbated by the fact that unit root tests generally have low power.

(1) Rapport and Reichlin (1989) note that all unit root tests have difficulty discriminating between an *I(1)* process and an *I(0)* process with a shift in its mean.

(1) The power of unit root tests depends much more on the span of the data, ceteris paribus, than on the number of observations.

(1) ADF tests are sensitive to non-linear transformations of the data, such as when a variable is found to be non-stationary in levels but stationary in logarithms (Kennedy, 1996).

2.4 ARCH Tests

Engle (1982) noticed that in many time series, particularly those involving financial data, large and small residuals tend to come in clusters, suggesting that the variance of an error may depend on the size of the preceding error. Thus, he developed ARCH, i.e. autoregressive conditional heteroscedasticity, a popular form of heteroscedasticity for time series data. Bollerslev (1986) has generalized ARCH to form GARCH, in which the conditional variance is also a function of past conditional variances. The key idea of ARCH is that the variance of μ_t, conditional on μ_{t-1}, is a linear function of the square of μ_{t-1}. The unconditional variance is constant, so OLS is BLUE, but because the conditional variance is heteroscedastic it is possible to fi nd a non-linear estimator, based on MLE considerations, that is more efficient. When the variance of μ_t depends on the squared disturbance term in the previous time period, it is called an ARCH(1) process, which can be written as:

$$\mathrm{var}(\mu_2) = \sigma_t^2 = \sigma + \beta\mu_{t-1}^2 \quad (3)$$

Table 3. Autocorrelation Tests

	Durbin-Watson	Breusch-Godfrey Test	
	DW statistic	*F* value of LM	*p*-value
KRW	2.05161	0.83966	0.4321
JPY	2.01063	0.28600	0.7513
CNY	1.96453	0.44234	0.6426

Note: KRW, JPY and CNY represent the exchange rate of Korean won, Japanese yen and Chinese yuan against the US dollar, respectively.
*, ** and *** indicate significance at the 10%, 5% and 1%, respectively.

If there is no auto correlation in the error variance, then H0: $\beta = 0$, in which case var(μ_t) = α, and there is the case of homoscedastic error variance. Engle (1982) has shown that a test of the preceding null hypothesis can be easily made by running the following regression:

$$\hat{\mu}_t^2 = \hat{\alpha} + \beta\hat{\mu}_{t-1}^2 \quad (4)$$

where denotes the OLS residuals estimated from the original regression model. The null hypothesis H_0 can be tested by the usual F-test. If ARCH effect is found to be present, it implies that variance of daily returns is serially correlated. In this situation it would be necessary to test whether changing variance can impact the expected mean of future returns. To this end, in order to investigate the possibility of the effects of serial correlation in variance and its impact on market efficiency, a GARCH-M(1,1) model (Bollerslev, 1986 and 1987), will be fitted to the first differences. This model may be specified as follows:

$$\Delta P_t = \beta + \gamma h_t^2 + \epsilon_t \quad (5)$$

$$h_t^2 = \alpha_0 + \alpha_1\epsilon_{t-1}^2 + \alpha_2 h_{t-1}^2 \quad (6)$$

where h^2 is the conditional variance of first differences (or daily returns). If γ is tested to be significantly different from zero, it implies a serial correlation of expected returns since conditional variance is serially correlated. Within the random walk model framework, this result would imply the presence of autocorrelation in the first difference time series, rendering the time series of returns predictable and the market inefficient.

Ⅲ. Empirical Findings

1. Autocorrelation Tests

The autocorrelation results based on the Durbin-Watson and the Breusch-Godfrey tests are presented in 〈Table 3〉. The null hypothesis of no autocorrelation is not rejected at the 5% level in all exchange rates data, suggesting that the three exchange rates are mostly independently distributed over the sample period.

2. Unit Root Test

〈Table 4〉 reports the results of the Augmented Dickey–Fuller unit root tests

Table 4. Unit Root Test

Variables	At Level		At First Difference	
	ADF t-statistic	p-value	ADF t-statistic	p-value†
KRW	-2.76810	0.0632*	-37.72167	0***
JPY	-2.15040	0.2251	-36.71487	0***
CNY	-1.43642	0.5656	-35.75932	0***
	PP t-statistic	p-value	PP t-statistic	p-value†
KRW	-2.62866	0.0874*	-37.82416	0***
JPY	-2.14475	0.2272	-36.71433	0***
CNY	-1.52510	0.5207	-35.97420	0***

Note: KRW, JPY and CNY represent the exchange rate of Korean won, Japanese yen and Chinese yuan against the US dollar, respectively.
† MacKinnon (1996) one-sided p-values.
*, ** and *** indicate significance at the 10%, 5% and 1%, respectively.

with drift (Model II) at both level and first difference series of exchange rates. The results indicate that the values of the three exchange rates are not significant at the 5% level. Therefore, the null hypothesis of the existence of unit root cannot be rejected, confirming that unit root exists in these three rates. Therefore the rates of Korean won and Japanese yen and Chinese yuan against the US dollar are believed to follow the random walks process at level

However, the existence of unit root in exchange rates do not necessarily imply that the rates are unpredictable. If the exchange rates are characterized by a white noise process, the data series are said to follow the random walk. In that case, the exchange rates are considered to be unpredictable. On the other hand, if the exchange rates do not follow white noise, or they are integrated of order one, *I(1)*, there exists some predictable constituents. Because the ADF tests are designed to investigate just the existence of stochastic trend constituents and do not identify whether the short-term fluctuations dictate the stochastic trend constituents, the ARCH tests need to be applied.

3. ARCH Tests

〈Table 5〉 reports ARCH(Autoregressive Conditional Heteroscedasticity) test of residuals among the exchange rates. The F-values of the three exchange rates are significant rejecting the null hypothesis of

Table 5. ARCH Tests

	ARCH *F*	Obs*R-squared	*p*-value
KRW	8.65856	8.61527	0.0033***
JPY	17.50257	17.59275	0***
CNY	34.56579	33.73661	0***

Note: KRW, JPY and CNY represent the exchange rate of Korean won, Japanese yen and Chinese yuan against the US dollar, respectively.
*, ** and *** indicate significance at the 10%, 5% and 1%, respectively.

Table 6. GARCH estimation

Variable	Coefficient	Std. Error	*z*-Statistic	*p*-value
Mean Equation : $\triangle p_t = \beta + \gamma h_t^2 + \epsilon_t$				
Variance Equation: $h_t^2 = \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \alpha_0 h_{t-1}^2$				
KRW				
β	11.58617	4.418735	2.622057	0.0087***
γ	0.989902	0.003882	255.0287	0***
α_0	-0.48093	1.081204	-0.44481	0.6565
α_1	0.027562	0.007039	3.915578	0.0001***
α_2	0.964262	0.008575	112.4556	0***
JPY				
β	0.774575	0.337891	2.292383	0.0219**
γ	0.993027	0.003042	326.3991	0***
α_0	-0.03084	0.009133	-3.37653	0.0007***
α_1	0.033566	0.006428	5.22216	0***
α_2	0.959953	0.007506	127.8862	0***
CNY				
β	0.02063	0.010556	1.954256	0.0507*
γ	0.996955	0.001588	627.9795	0***
α_0	-0.00019	5.78E-05	-3.19885	0.0014***
α_1	0.19695	0.022267	8.844979	0***
α_2	0.425069	0.061132	6.953273	0***

Note: KRW, JPY and CNY represent the exchange rate of Korean won, Japanese yen and Chinese yuan against the US dollar, respectively.
*, ** and *** indicate significance at the 10%, 5% and 1%, respectively.

no ARCH effect. Therefore, there exists the ARCH effect in each of these exchange rates. Therefore a GARCH-M(1,1) model is fitted to the first differences, assuming the conditional distribution of the errors to be t-distributed, i.e. $\triangle p_t = \beta + \gamma h_t^2 + \epsilon_t$, $h_t^2 = \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \alpha_0 h_{t-1}^2$.

4. GARCH Model

〈Table 6〉 shows the results of the GARCH-M(1,1) model estimation. The γ values of the exchange rates are all significant at the 5% level, indicating that there is evidence of a GARCH effect in data series of the three exchange rates. Overall results of ARCH and GARCH estimation suggest that (a) the market cannot transmit information which exists in the variance of daily exchange rates fast enough each day for all the data, leading to serial correlation in conditional variance of exchange rates, and (b) this serial correlation may impact daily exchange rates, causing autocorrelation in the time series. These results can imply the breakdown of key assumptions of this model, suggesting that exchange rates under study do not follow a random walk process.

IV. Conclusion

We examined the efficiency of the spot exchange rates of Korean, Japanese and Chinese currencies against the US dollar. To this end, various tests have been performed to find out whether the exchange rates in the spot foreign exchange markets follow a random walk process as required by the efficient market hypothesis. The daily data of the period from January 1, 2015 to January 30, 2020 for the exchanges rates of the three biggest economies in Asia were examined. Three methods are used to test for random walk hypothesis: autocorrelation tests, unit root tests and GARCH-M(1,1) model estimation.

The results of the tests showed that no autocorrelation exists in all data series and that all of the series have a unit root. According to the test results, the foreign exchange markets in Korea, Japan and China follow the random walk, appearing to imply that the markets in three countries are efficient. The results of the ARCH test indicate that the ARCH effect exists in the series of the exchange rates data, suggesting that significant heteroscedasticity is existent in the three exchange rates. Therefore, a GARCH-M(1,1) model is fitted for each of the series. The GARCH model estimation indicates that there is a GARCH effect in series of three exchange rates, suggesting that exchange rates under study do not follow a random walk process. Overall, based on these results, it is assumed that the exchange rates against the US dollar of Korean, Japanese and Chinese currencies does not follow a random walk since the all the data series of the three exchange rates do not pass three conditions of weak-form market efficiency set by this study, and in this respect, it might be said to be informationally inefficient. These findings have practical implications for both individual and institutional investors to be able to obtain excess returns on their investments in the foreign exchange markets in three countries by using appropriate risk management, portfolio strategy, technical analysis, etc.

This study provides the first empirical examination on the foreign exchange market efficiency in the three biggest economies in Asia including China, which has been excluded from research due to its exchange rate regime. As a result, this paper can contribute to invoke further research on this area. Another notable contribution of this study is that to address heteroscedasticity in the exchange rate time series and its possible shock on a random walk model, a GARCH-M(1,1) model was applied which is a key constituent of our examination on the efficiency of the foreign exchange markets in Korea, Japan and China.

There exist some limitations. The findings of the studies may be different depending on the methodology employed, sampling period used, and date frequency as seen in a large number of previous research. For future researcher on this area, therefore, consideration should be given to these issues to attain significant implications for investors and policy makers.

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