THE ANALYSIS OF EFFICIENT FOREIGN EXCHANGE MARKET IN CHINA

by

Xi (Susan) Chen

Supervisor
Thanasis Stengos

Second Reader
Yiguo Sun

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DEPARTMENT OF ECONOMICS

UNIVERSITY of GUELPH

Abstract

Efficient market theory provides an important basis for the modern Capital Asset Pricing theory and other financial theories, and simplifies many variables into concise statistical formulas. Applying the securities market model to the FX market raises the issue of "market efficiency" which needs to be addressed before we can use "stock market theory" to analyse the characteristic of exchange rate fluctuation which are based on Efficient Market Hypothesis (EMH).

On July 21, 2005, the People's Bank of China issued a public announcement that China began to implement the managed floating exchange rate system, pegging the RMB to a basket of currencies, based on market supply and demand. The exchange rate of RMB was no longer pegged to single dollar, and a more flexible form of the exchange rate mechanism was adopted. One of the theoretical foundations of applying EHM to study Chinese foreign exchange (FX) market is satisfied, combining both theoretical and practical elements.

Based on above explanations, this paper presents EMH as the theoretical cornerstone of Chinese FX market studies. Through the empirical tests of FX market efficiency in China, we can further understand this hypothesis in theory. What's more, we have always studied FX market efficiency only based on qualitative research, but in this paper I will use abundant, detailed data, statistical and econometrical measures based on quantitative research to test market efficiency. This innovative approach provides a fresh perspective to study FX market efficiency in China. In addition, this paper will attempt to trace the root of the low efficiency FX market in China through the empirical tests for efficiency.

Keywords: Foreign exchange market, Efficient Market Hypothesis, Random walk model, Market Maker.

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Chapter 1 Introduction

1.1 Background and implication

Since the collapse of the Bretton Woods system, the exchange rates among major currencies have fluctuated dramatically. This fluctuation not only influences the establishment of government policies, but also challenges the traditional theory of the exchange rate. In the past, exchange theory was dominated by the linearity paradigm. There are some milestone theories in this field like the Balance of Payments Theory, the Theory of Purchasing Power Parity, the Psychological Theory of Exchange, and the Monetary and Exchange Rate theory. These theories were set up based on a linear model and developed significantly in recent decades. However, with the rapid development of technology and globalization, international capital flows have accelerated. In such a constant changing world, the interaction of economic variables is becoming more and more complicated and the exchange rate is revealed to be volatile, complex and unpredictable. As a result, there have been considerable changes in the applicable scope, conditions, and measures of those classic theories, which have caused conflict between realistic problems and theoretical applications.

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1.2 Related Research

Foreign scholars made significant progress in the field of stock market efficiency. They have put forward the test methods and conclusions for the stock market in terms of weak efficiency form, semi-strong efficiency form and strong efficiency form. At the same time, some scholars have transplanted the study of stock market, applying it to the FX market to measure its efficiency with great success.

The efficient-market hypothesis emerged as a prominent theoretic position in the mid-1960s. Eugene Fama is most often thought of as the father of the efficient market hypothesis. He published a review of both the theory and the evidence for the hypothesis in 1970, titled "*Efficient Capital Markets: A Review of Theory and Empirical Work*," and proposed a related regression model in 1985. In China's academia, Li extended and refined this theory, by publishing the book "*Currency exchange rate theory and policy research*" in 1999, which has contributed to the development of EMH theory in last century.

1.3 Research idea and purpose

This paper links theoretical study to the actual operation of the FX market in China in order to study the efficiency of this market through empirical research methods.

The purposes of this paper are as follows:

1.3.1. Analyzing the FX market efficiency in China by using the FX data since July 21, 2005.

1.3.2. Finding out the reasons for inefficiencies and making suggestions to improve the efficiency of the FX market in China according to the empirical results.

1.4 Structure

According to the above idea and purpose, this paper is organized as follows:

The first part of this paper will summarize current research of FX market efficiency both in China and abroad. The second part will introduce the EMH Theory and its development. The third part will introduce the model theory beginning with the random walk model, runs test model and Ljung-box test model. Then, based on these models, empirical tests will compare the exchange rate of RMB with the dollar, yen, euro and Hong Kong dollars after July 21, 2005 in order to test the efficiency of the FX market and analyze test results. This is the key part of this paper .The fourth part will analyze the reasons for the inefficiencies of the Chinese FX market ,and will present recommendations for improvements including the implement action of a market-maker system.

1.5 Innovative elements

I have researched a great deal of literature in this field. Despite the significant body of research, imperfections still exist.

The innovative elements of the current project cover three aspects:

1.5.1 Data selection. This paper will use directly the time series data from China FX market, since July 21, 2005 for empirical test, and conclusions are more convincing than the conclusions which were obtained from the previous time series data before the formation mechanism of exchange rate changes.

1.5.2 Empirical tests. This paper will apply the method of testing the efficiency of the stock market into FX market.

1.5.3 Use of Statistics and Econometrics tools. Eviews, Stata, and Excel2007 are used by this paper.

Chapter 2 Emergence and development of EMH

2.1 Emergence of EMH and forms

The main function of capital market is re-distributing the capital ownership of economy. Thus, the ideal price in capital market should be the signal of resource allocation. On the condition that the stock price can fully respond the all reachable information, the company could make right decision on production and investment, in addition, the investor could rightly choose the stock which can indicate enterprise ownership. If a stock price in the market can always fully respond the information we can get, the market is "efficiency".

The EMH was developed by Professor Eugene Fama at the University Of Chicago Graduate School Of Business as an academic concept of study through his published Ph.D. thesis in the early 1960s at the same school.

The efficient-market hypothesis states that it is impossible to consistently outperform the market by using any information that the market already knows, except through luck. Information or news in the EMH is defined as anything that may affect prices that is unknown in present and thus unpredictable in the future.

"In an efficient market, competition among the many intelligent participants leads to a situation where, at any point in time, actual prices of individual securities already reflect the effects of information based both on events that have already occurred and on events which, as of now, the market expects to take place in the future. In other words, in an efficient market at any point in time the actual price of a security will be a good estimate of its intrinsic value."[1] There are three forms of the efficient market hypothesis: weak, semi-strong and strong efficiency.

1. The **"Weak" form** indicates that all past market prices and data are fully reflected in securities prices. In other words, technical analysis[2] is of no use, though some forms of fundamental analysis may still provide excess returns. Share prices exhibit no serial

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[1] Eugene F. Fama, "Random Walks in Stock Market Prices," *Financial Analysts Journal*, September/October 1965 (reprinted January-February 1995).

[2] **Technical analysis** is a financial markets technique that claims the ability to forecast the future direction of security prices through the study of past market data, primarily price and volume.

dependence, meaning that there are no "patterns" to asset prices .This implies that future price movements are determined entirely by unexpected information and therefore are random.

2. The **"Semi-strong" form** asserts that all publicly available information is fully reflected in securities prices, and no excess returns can be earned by trading on that information.In other words, fundamental analysis[3] is of no use.

3. The **"Strong" form** asserts that all information (public and private) is fully reflected in securities prices, and no one can earn excess returns.In other words, even insider information is of no use.

2.2 The characteristics of an efficient market

2.2.1 In the efficient market, the change of stock price is random from one period to next. Because in this market, the information flow is at any time random, uniform distribution. The investor is rational and they all make the reaction to the information flow changes. Moreover, because of the depth and breadth, strong elasticity and the Efficient Function Mechanism of the market, nobody can control the stock price by their decision and prediction, and cannot influence the trend of the stock price system. That means no one could gain excess profit from their technical analysis.

2.2.2 Stock price should be responded promptly, accurately to the new information about pricing. Once the information has been released, the investors evaluate and assess the stock price using that information, in order to reflect rightly the excessive deviation of price and value leading by the increase or decrease of company's performance. This estimate will respond to the stock price rapidly. Then, the price in the market will do the random walk around the new value until new information appears which changes the value, and then the investors will make another adjustment.

2.2.3 In an efficient stock market, the stock price fluctuates around the intrinsic value, and the price is unbiased in terms of reflecting instinct value. That means $E(\widehat{P}) = P$ (the expectation

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[3] **Fundamental analysis** of a business involves analyzing its financial statements and health, its management and competitive advantages, and its competitors and markets.

value of stock price equals its true value) in an efficient market. When some investors misprice the information into value, stock price may overreact. The rest of investors may take opposite moves upon receiving such information, force price fall back to its intrinsic value and fluctuates randomly until the next piece of information emerges to bring intrinsic value to the next equilibrium point. Paul A.Samuelson indicated that the price efficiency can be considered as the best valuation for intrinsic value of stock at any time.

2.2.4 Efficient market price securities according to their risk. This is because prices in an efficient market have already factored in all historical information. So when information emerges, prices change to account for that new information, thus profit and loss is generated. So the price generated by efficient market comes hand to hand with risk.

2.2.5 In an efficient market, the existing shareholders face all the risk which is brought by the new information. Once there enters new information, the stock price responds to it instantly. This change can only be undertaken by existing investors, and non-investors only accept the changed prices. Thus, there is no excess return and arbitrage opportunities in an efficient market, only the long term investors can get the benefit from this efficient market.

2.3 EMH empirical Implications

2.3.1 General theory

Market efficiency hypothesis is a description of prices in competitive markets that respond fully to new information. This statement is very general, lack of the test of principal. Therefore, we have to study the formation of price to make this theory testable. To define what is "fully respond", it involves two necessary definitions: "Martingale" and "Fair game".

1 . Martingale and Fair game

For stochastic processx_t, if

$$E_t(x_{t+1} \mid \phi_t) = x_t \tag{2.1}$$

ϕ_t is the information set at time t,(assume including), we call x_t as Martingale.

From above, if x_t is a Martingale, under the information set ϕ_t, the optimal estimation of x_{t+1} is x_t. Or, we can generally say that the conditional expected value of the next observation, given all the past observations, is equal to the last observation.

For stochastic process Z_t, if $E_t(Z_{t+1}|\phi_t)=0$, Z_t is a "fair game". (The mathematical expectation of the speculator is zero) Martingale hides $x_{t+1}-x_t$, which is a fair game:

$$E_t(x_{t+1}-x_t \mid \phi_t)=0 \qquad (2.2)$$

Obviously, if and only if $x_{t+1}-x_t$ is a fair game, x_t is a Martingale. Because of that, "fair game "is sometimes called "Martingale Difference".

"Fair game "model (2.2) shows in the information set ϕ_t and the incremental price is not predictable. From this viewpoint, the information fully responds and concentrates on price, so the predication for rate of Return is of no use.

2.3.2 The application of EMH in FX market

As a vital part of financial market, FX market is closely related to capital market, money market and goods market. Foreign currency, as same as stock and bond, is a significant financial asset, therefore, the efficiency theory for FX market eventually becomes a major part of EMH. Efficient market indicates that price mechanism can be made of use, which means price can roughly report the value of financial assets. In that case, the efficient FX market means that the exchange rate of each currency can reflect its value. In an efficient market, it should satisfy the following conditions:

$$s_t = s_t^e + U_t \qquad (2.6)$$

$$s_t^e = f_{t-1} + U_t \qquad (2.7)$$

s_t is the future real spot exchange rate; s_t^e is the expected spot exchange rate; f_{t-1} denotes the forward exchange rate and U_t is a term of stochastic error.

The two equations above indicate that, in an efficient market, they would not make systematic mistakes due to rational expectations of the consumers. The gap between future real spot exchange rate and expected spot exchange rate is only a term of stochastic error, which is the same as the gap between future real spot exchange rate and forward exchange rate.

Chapter 3 The empirical test on efficiency of FX market in China

According to the classification of EMH, the levels of efficiency are: strong form market→semi-strong market→weak market and the strong form market is the highest form of efficient market. A market must be a weak efficient market first and then be a semi-strong or strong form market gradually. Therefore, evaluating the efficiency of a market, we should analyze that whether this market has weak form efficiency or not.

Based on the theory of efficient FX market, lots of scholars applied different econometric methods to test the efficiency of FX market in developed countries under floating exchange rates, and gave various suggestions and recommendations to the managers who take charge in the FX markets around world depending on the test results.

3.1 Random walk test

3.1.1 The random walk model and market efficiency

Bachelier is considered a pioneer in the study of random walk model. He put forward that the market follows random walk that can be modeled by standard normal distribution, but he barely gave any evidences to prove it. Maurice (1953) found it: It is impossible to ensure any predictable forms of stock prices, and the development of stock prices is stochastic. The previous data can not offer any measures to predict the trend of stock prices.

By adjusting the stock prices, the efficient market had already counted the available information in, including the fundamental factors and the price history. Therefore, the prices change only when the new information is available. We cannot gamble in an efficient market, not only because the prices already responded to the known information, but also a great number of investors guarantee the fairness of price. In fact, what EMH is really saying is that, the market is formed by a great number of participants. The numbers is so huge that participants on the whole cannot make mistakes. Of the yield is independent, and then they are random variables that follows a random walk path. This is the "random walk" version of EMH, however, EMH does not necessarily contain random walk, but random walk implies the underlying efficiency in the market. (Peters 1996) This means, random walk is only a sufficient condition of Weak form EMH, not a necessary one. Therefore, if market movements follow Random Walk, then the market is in its weak form of efficiency, but we cannot conclude the market is inefficient merely if no random walk path is evidenced.

Firstly, the definition is: If the change of time series variable P_t from one period to another is stochastic, that means if we can get

$$p_t = p_{t-1} + \varepsilon_t \tag{3.1}$$

Where $\{\varepsilon_t\}$ is Independent and identically-distributed (i.i.d), and $E(\varepsilon_t) = 0, D(\varepsilon_t) = E(\varepsilon_t^{\,2}) = \sigma^2 < \infty$

We can simply define it as: If the changes of time series variable from one period to another equals the drift term d, plus an error term, then we can get

$$p_t = p_{t-1} + d + \varepsilon_t \tag{3.2}$$

$$p_t - p_{t-1} = d + \varepsilon_t \tag{3.3}$$

So it is said that ε_t changes as a random walk. $\{\varepsilon_t\}$ is subjected to i.i.d, $E(\varepsilon_t) = 0, D(\varepsilon_t) = E(\varepsilon_t^{\,2}) = \sigma^2 < \infty$.

If we assume that the market predication is reasonable, the market equilibrium denotes as:

$$f_t^{t+1} = E_t S_{t+1} + \rho_t \tag{3.4}$$

The left side of the equation is the logarithm of U.S dollar forward entering at time t, and settling at time t+1, ρ_t is the market risk premium. The equation stands the efficient market equilibrium, because forward FX rate already contains all public information and rational market expectation $E_t S_{t+1}$, and the risk premium shows the attitude of market for the risk. Subtract S_{t+1} on both sides, and then we get:

$$f_t^{t+1} - S_{t+1} = (E_t S_{t+1} - S_{t+1}) + \rho_t \qquad (3.5)$$
$$= \varepsilon_t + \rho_t$$

where ε_t is an important term here, because it replaces the content which was in the parentheses on the right. The equation summarizes EMH that: Forward rate and the spot exchange rate at the maturity date of the futures contract are different. The gap between them is the sum of two terms on the right: One term is completely random expectation error, and the other is risk premium.

We can prove that:

(1) The random walk model is consistent with the efficiency problem.

However, on the other hand,

(2) The efficiency itself doesn't require the random walk on spot rate. If the spot rate subjects to biased random walk, then

$$S_t = S_{t-1} + d + \varepsilon_t \qquad (3.6)$$

Take exp. value based at time t-1, we get:

$$E_{t-1} S_t = E_{t-1} S_{t-1} + E_{t-1} d + E_{t-1} \varepsilon_t \qquad (3.7)$$

$$E_{t-1} S_t = S_{t-1} + d \qquad (3.8)$$

This is because that we assume at time t, S_{t-1} is known,(constant) drift term "d" is known as well, and the expectation of random error term ε_t always equals zero in next period. Thus, under random walk, the predication of spot rate in the next period is simply the current observed exchange rate adds or subtracts any possible drift term. Under the condition of without drift term, an investor's best predication is: the exchange rate at next period equals to the current one. In fact, without drift term, at time t-1 , S_{t-1} indicates the expectation of all future spot rates.

3.1.2 Introduction of unit root test, Ljung-Box test and runs test

3.1.2.1 Unit root test

A unit root test tests whether a time series variable is non-stationary.

If the process has a unit root, then it is a non-stationary time series。 That is, the moments of the stochastic process depend on *t*.

- If stochastic time series Y_t meets the following, then Y_t is stationary.
- Mean value： $E(Y_t) = \mu_t$ (constant)
- Variance： $var(Y_t) = \sigma^2$ (constant)
- Covariance： $\gamma_k = E[(Y_t - \mu_t)(Y_{t+k} - \mu_t)]$

A stochastic process y_t, $\{y_{t,}t = 1,2,3,4...\}$, if $y_t = \rho y_{t-1} + \varepsilon_r$, $\rho = 1$, then this process has a unit root. If the process has a unit root, then it is a non-stationary time series.

In addition, if $y_t = y_{y-1} + \varepsilon_t$, ε_t subjected to i.i.d, $E(\varepsilon_t) = 0, D(\varepsilon_t) = E(\varepsilon_t^2) = \sigma^2 < \infty$, y_t is a Random walk process.

Unit root process is integrated if taking only one difference yields a stationary process, for example, $y_t - y_{t-1} = (1 - B)y_{t-1} = \varepsilon_t$ denoted as I(1). Normally, a process is Integrated if taking "d" times differences yields a stationary process, denoted as I(d). "d" means the number of unit root in this series. If d=0, then I (0) means a stationary time series.

There are several ways to test unit root. Here can we use Dickey Fuller test.

A). Dickey Fuller test

Considering an AR (I) process

$$y_t = \rho y_{t-1} + \varepsilon_t \tag{3.12}$$

Where ε_t is the white noise. If parameter is $|\rho| < 1$, then series y_t is stationary. A unit root is present if $|\rho| = 1$. The model would be non-stationary in this case. Naturally it would be even more non-stationary if $|\rho| > 1$. So we only have to test whether is strictly $|\rho| < 1$.

The regression model can be written as (3.12)

Equals： $Y_t - Y_{t-1} = \rho Y_{t-1} - Y_{t-1} + \varepsilon_t$

Equals： $Y_t - Y_{t-1} = (\rho-1)\, Y_{t-1} + \varepsilon_t$

Equals： $\Delta Y_t = r\, Y_{t-1} + \varepsilon_t$ (3.13)

Where r= ρ-1 , so, this model can be estimated and testing for a unit root is equivalent to testing $r = 0$

$$H_0 : r=0, \qquad H_1 : r<0$$

Under the null hypothesis, it is not possible to use standard t-distribution as critical values. Therefore this statistic τ has a specific distribution simply known as the Dickey-Fuller table.

Besides the (3.13) model, there are other two versions of the tests:

Test for a unit root with drift: $\Delta y_t = c + r y_{t-1} + \varepsilon_t$ (3.14)

Test for a unit root with drift and deterministic time trend:

$$\Delta y_t = c + \sigma_t + r y_{t-1} + \varepsilon_t \qquad (3.15)$$

Normally, if the series y_t fluctuates around zero mean value, then we should choose the version of no drift and deterministic time trend, equation (3.13). If series has non-zero mean value, but no time trend, it's better to choose equation (3.14). Similarly, if the series has a descending or ascending trend along with the change of time, we adopt the form of (3.15).

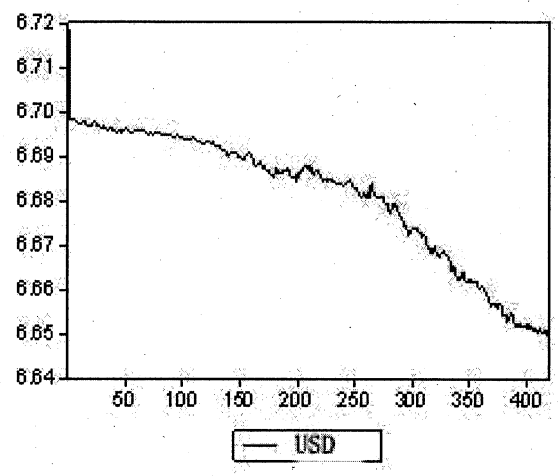
B). Augmented Dickey-Fuller test (ADF)

For a larger and more complicated set of time series models， we use Augmented Dickey Fuller test （ADF） which removes all the structural effects (autocorrelation) in the time series。It is applied to the model

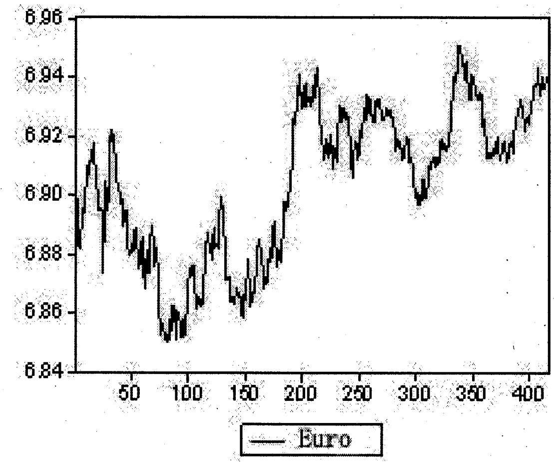
$$\Delta y_t = r y_{t-1} + \xi_1 \Delta y_{t-1} + \xi_2 \Delta y_{t-2} + \xi_3 \Delta y_{t-3} + \ldots\ldots + \xi_{p-1} \Delta y_{t-p+1} + \varepsilon_t \qquad (3.16)$$

This test uses the same procedure as DF test.

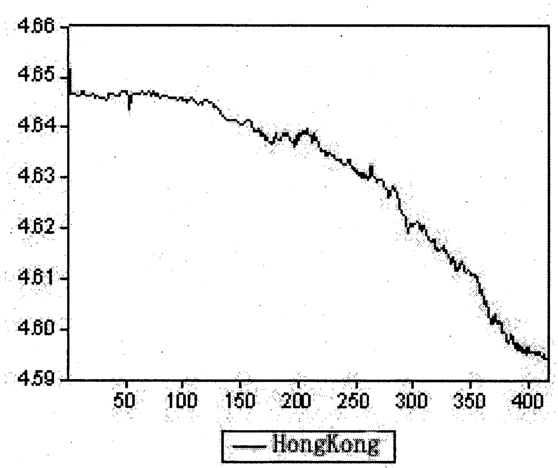
Sequence Diagram[4] of U.S dollar, Euro, HK dollar and Japanese Yen as following:



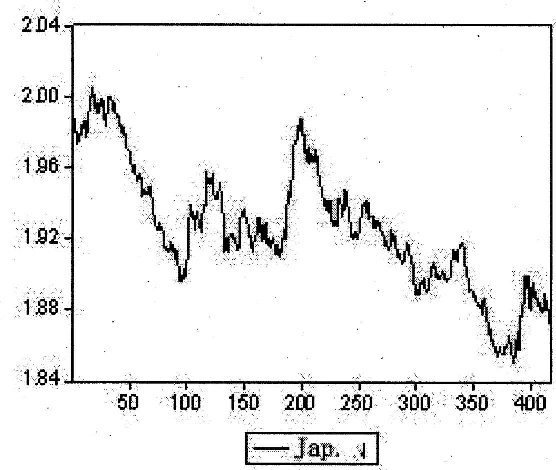
RMB/100USD Sequence Diagram



RMB/100 Euro Sequence Diagram



RMB/100 HK Dollar Sequence Diagram



RMB/100 Japanese Yen Sequence Diagram

From the above Sequence Diagrams, since 21st July 2005(the first trading day) to 5th April 2008, RMB is appreciating against USD, HK dollar and Japanese Yen, and in the diagrams of RMB against Euro, RMB is depreciating lightly. Therefore, we would better choose the model which contains constant term and deterministic time trend :

$$\Delta y_t = c + \sigma_t + r y_{t-1} + \varepsilon_t \tag{3.15}$$

[4] A **sequence diagram** is a kind of interaction diagram in UML, which shows how processes operate one with another and in what order.

Data sources:

This paper will choose U.S dollar, Euro, Japanese Yen and HongKong dollar as research objects, the sample data drawn from the interval of 21st July 2005 (the first trading day) to 5thApril 2008 when the reformation of the FX mechanism took place in China. All the data was downloaded directly from State Administration of Foreign Exchange. *(http://www.safe.gov.cn/model_safe_en/index.jsp)* I used Eviews and Stata as the statistical software.

Result of unit root test:

Each version of the test has its own critical value which depends on the size of the sample.

1. USD unit root test result

Augmented Dickey-Fuller test statistic		-1.396074
Test critical values:	1% level	-3.445776
	5% level	-2.868235
	10% level	-2.570401

From the result table of ADF test, we know that the sample size is 419, and the statistic value is -1.396047 which is bigger than the critical value at 1% significance level. Therefore, the null hypothesis fails to be rejected, which means that the series has a unit root and is non-stationary.

2. HongKong dollar unit root test result

Augmented Dickey-Fuller test statistic		-0.801504
Test critical values:	1% level	-3.980272
	5% level	-3.420662
	10% level	-3.133035

According to ADF statistic table, the sample size is 419, and the statistic value is -0.801504, which is bigger than the critical value at 1% significance level. Therefore, the null hypothesis fails to be rejected, which means that the series has a unit root and is non-stationary

3. Japanese Yen unit root test result

Augmented Dickey-Fuller test statistic		-2.508158
Test critical values:	1% level	-3.980272
	5% level	-3.420662
	10% level	-3.133035

According to ADF statistic table, the sample size is 419, and the statistic value is -2.5081584 which is bigger than the critical value at 1% significance level. Therefore, the null hypothesis fails to be rejected which means that the series has a unit root and is non-stationary

4. Euro unit root test result

Augmented Dickey-Fuller test statistic		-3.082172
Test critical values:	1% level	-3.980271
	5% level	-3.420662
	10% level	-3.133035

According to ADF statistic table, the sample size is 419, and the statistic value is -3.08217213, which is bigger than the critical value at 1% significance level. Therefore, the null hypothesis fails to be rejected which means that the series has a unit root and is non-stationary

Although we know the above series have unit root, we still don't know whether ε_t is serially correlated or not.

3.1.2.2 Ljung-Box test

The test statistic is:

$$Q = n(n+2)\sum_{j=1}^{h}\frac{\rho_j^2}{n-j}$$

where n is the sample size, ρ_j is the sample autocorrelation at lag j, and h is the number of lags being tested.

For significance level α, the critical region for rejection of the hypothesis of randomness is rejected if $Q > X^2_{1-a,h}$

where $X^2_{1-a,h}$ is the chi-square distribution with h degrees of freedom at significance level α.

Here, setting the null and alternative hypotheses as:

Ho: □$\rho(1) = \rho(2) = \cdots = \rho(h) = 0$

H1: some of $\rho(s) \neq 0$

The table below is the Q value with different h levels.

h(lag)	1	5	10	15□	20	25	30	□35□	40
US(Q)	0.0513	0.1763	0.0135	0.0484	0.0684	0.0761	0.0901	0.1504	0.1596
EURO(Q)	0.5120	0.4474	0.4699	0.4258	0.5433	0.6453	0.3962	0.2128	0.2385
JAP(Q)	0.0576	0.0381	0.0330	0.0714	0.2323	0.1781	0.0553	0.0190	0.0457
HK(Q)	0.0103	0.1307	0.1620	0.3851	0.3221	0.5747	0.5651	0.6555	0.6768

From above, the P-value* is smaller than 10% significance value in the US and JAP FX market. There exists residual serial correlation. I did reject the null Hypotheses. In EURO market, we cannot reject Ho at the significance level 10%. The error term is a serially uncorrelated. And in FX market of HK dollar, only at h=1, we do reject Ho. So we can say that there is no enough evidence for proving the FX market of these four currencies against RMB is random walk or not.

3.1.2.3 Runs test

The hypothesis of Runs test is: there is no obvious trend for the time sequence of the fluctuation of FX, which means the FX is stochastic, and the consequences are mutually independent.

One "Run" was defined as stock price keeps a continuous sequence with the same sign, and the "length" means the number of runs in a sequence.

There are three cases for a daily change in exchange rate: Appreciation, depreciation and even. Make N the total number of days of FX swings and that is also the sample size. There are N_1 days of appreciation and even, and N_2 days of depreciation, so $N = N_1 + N_2$. Use "m" to represent the number of the runs. Based on the formula Fama introduced, the mean value and standard deviation of a run can be denoted as:

$$E(m) = \frac{2N_1N_2}{N} + 1 \qquad (3.17)$$

$$\sigma_m = \left[\frac{2N_1N_2(2N_1N_2 - N)}{N^2(N-1)}\right]^{\frac{1}{2}} \qquad (3.18)$$

For large samples, format a statistic:

$$Z = \frac{m - E(m)}{\sigma_m} \qquad (3.19)$$

According to Law of Large Numbers, Z is gradually subject to N (0, 1) distribution. At significance level α, If $|z|$ is not bigger than the critical value, we accept at the null hypothesis, indicating that the FX sequence pass the runs test, and the FX swing doesn't have an obvious trend. Otherwise, if $|z|$ is bigger than the critical value, we will reject the null hypothesis, failing to the runs test, and it indicates that the FX swing potentially has a trend.

Results of Runs test:

1. FX market of USD against RMB

$$N = 419,\ N_1 = 319,\ N_2 = 180\ ,\ \ m=105,$$

$$E(m) = \frac{2N_1N_2}{N} + 1 = \frac{2 \times 319 \times 180}{419} = 273$$

$$\sigma_m = \left[\frac{2N_1N_2(2N_1N_2 - N)}{N^2(N-1)}\right]^{\frac{1}{2}}$$

$$= \left[\frac{2\times319\times180\times(2\times319\times180-419)}{419^2\times(419-1)}\right]^{\frac{1}{2}} = 13.6$$

$$Z = \frac{m-E(m)}{\sigma_m} = \frac{105-273}{13.6} = -4.95$$

$$|Z| = 4.95$$

At the significant level $\alpha = 0.01$, the critical value for standard normal distribution is 2.58. Since $|Z| = 4.59 > 2.58$, the null hypothesis was rejected, and it didn't pass the runs test which indicates that the FX market of USD against RMB is not a random walk process.

2. FX market of Euro against RMB

$$N = 417,\ N_1 = 208,\ N_2 = 209,\ m = 109$$

$$E(m) = \frac{2N_1N_2}{N} + 1 = \frac{2\times208\times209}{417} = 209.5$$

$$\sigma_m = \left[\frac{2N_1N_2(2N_1N_2 - N)}{N^2(N-1)}\right]^{\frac{1}{2}}$$

$$= \left[\frac{2\times208\times209\times(2\times208\times209-417)}{417^2\times(417-1)}\right]^{\frac{1}{2}} = 10.19$$

$$Z = \frac{m-E(m)}{\sigma_m} = \frac{109-209.5}{10.19} = -9.85$$

$$|Z| = 9.85$$

At the significance level $\alpha = 0.01$, the critical value for standard normal distribution is 2.58. Since $|Z| = 9.85 > 2.58$, the null hypothesis was rejected, and it didn't pass the runs test which indicates that the FX market of Euro against RMB is not a random walk process.

3. FX market of Japanese Yen against RMB

$$N = 417, N_1 = 237,\ N_2 = 180,\ m = 107$$

$$E(m) = \frac{2N_1N_2}{N} + 1 = \frac{2\times 237\times 180}{417} = 207$$

$$\sigma_m = \left[\frac{2N_1N_2(2N_1N_2 - N)}{N^2(N-1)}\right]^{\frac{1}{2}}$$

$$= \left[\frac{2\times 237\times 180\times(2\times 237\times 180 - 417)}{417^2\times(417-1)}\right]^{\frac{1}{2}} = 10$$

$$Z = \frac{m - E(m)}{\sigma_m} = \frac{107 - 207}{10} = -10$$

$$|Z| = 10$$

At the significant level $\alpha = 0.01$, the critical value for standard normal distribution is 2.58. Since $|Z| = 10 > 2.58$, the null hypothesis was rejected, and it didn't pass the runs test which indicates that the FX market of Japanese Yen against RMB is not a random walk process.

4.FX market of HongKong dollar against RMB

$$N = 417, N_1 = 287, N_2 = 130, m = 101$$

$$E(m) = \frac{2N_1N_2}{N} + 1 = \frac{2\times 287\times 130}{417} = 180$$

$$\sigma_m = \left[\frac{2N_1N_2(2N_1N_2 - N)}{N^2(N-1)}\right]^{\frac{1}{2}}$$

$$= \left[\frac{2\times 287\times 130\times(2\times 287\times 130 - 417)}{417^2\times(417-1)}\right]^{\frac{1}{2}} = 8.76$$

$$Z = \frac{m - E(m)}{\sigma_m} = \frac{101 - 180}{8.76} = -9.01$$

$$|Z| = 9.01$$

At the significant level $\alpha = 0.01$, the critical value for standard normal distribution is 2.58. Since $|Z| = 9.01 > 2.58$, the null hypothesis was rejected, and it didn't pass the runs test which indicates that the FX market of HongKong dollar against RMB is not a random walk process.

4. Conclusion

4.1 Test results

•Seen from the ADF test results, the time series of daily exchange rate for USD, Euro, HK dollar and Japanese Yen against RMB accepts the null hypothesis at the significance level 10%.That means the series has unit root. Moreover, through the Ljung-box test, the null hypothesis was rejected in some FX market, but was failed to be rejected in other FX market as well. Therefore, we don't have enough evidence for verifying the exchange rate of four foreign currencies against RMB is random walk or not.

•According to the time series of daily FX, we get the statistic $|z|$ value by using runs test which is bigger than the critical value at the significant level 10%. We rejected the null hypothesis and failed to the runs test which demonstrated that the FX swing has a tendency.

4.2 Reasons and suggestions for the low efficiency in FX market

• Limited currency products

The interbank FX market is skewed in both the composition of currency being traded and market structure. This has something to do with the Central banks's FX rate guarantee system within the pegging mechanism to the USD.

•Dominance of spot market

From 1994 to 2005 7, the interbank FX market is merely a spot market, until August, 2005 government lifted restrictions on interbank forward trading and swap. Nonetheless, according to market volume, spot market still domains for a long period of time since then. Forward was introduced into retail FX market as late as in 1997, when Bank of China was the first offering FX forward dealing and settlement service. After 2002, the Big four Banks in China (bank of china, industrial& commercial bank of china, china construction bank, agricultural bank of china,) plus bank of communication, CITIC bank of china and merchant bank of china were subsequently granted licenses. Due to the lack of a functional interbank FX market, left huge currency exposure in Bank's books unhedged. The single market type limited the growth of the market trading volume, also the domestic corporation and financial institutions seeking for hedge their FX risk cannot find the right tool. Given domestic financial institution has accumulated experiences in Risk Management and Derivatives, and emergence of domestic money market. Introducing interbank FX forward market becomes essential to fulfill the demands for diversified currencies which was brought by the transformation of China's currency policy,

• Dominance of USD

Since the establishment of Interbank FX market, USD, HKD, YEN and Euro and the only currency paired offered for spot trading against RMB, in which USD is the biggest chunk, until the introducing of 4 more currencies pairs in 2005.in the past 10 years, USD/RMB volume has always been above 90% of total volume, even with the introducing of EUR, which only took a small share from USD. In 2004, USD/ RMB volume has reached at peak of 97.78%, china's pegging system to USD had pushed the central bank into the market to intervene. However, market participants become dependent on central bank intervention, and market anticipation of intervention has lowered the activities in FX trading. With the introducing of new currencies pairs, hopefully this situation would improve.

• Monopoly power of market participants.

China's interbank FX market processes both characteristic of a monopoly buyer and monopoly seller. In 2002, Bank of China is the biggest seller of FX, accounts for more than 50% of the entire market value of currency sold. On the other hand, Central bank is the net buyer of FX, who bought 68% in 1995-2004, surged to 90% in 2004 of the entire interbank market.

• Small trading volume

Small trading volume can be reflected in terms of market depth and breadth, which are important market indicators measuring liquidity. When pegging with a basket of diversified currencies, lacking of market depth and breadth has not benefit in smoothing volatility. With the increased flexibility in RMB's pegging system, this could be potential obstacle of transformation of FX mechanism. In terms of trading volume, china's FX market features with small daily volume of just 830 million USD in 2004 , 0.11% of UK, 0.18% of US, even less than 1% of major Asian markets like Tokyo, Singapore and HongKong. However, from historical data, the growth in trading volume in recent years is unprecedented, apart from the fundamental factors of the economic growth, there are short terms factors such as international "HOT Money" speculating on RMB's appreciation.

Corresponding to these reasons, the researchers have presented some recommendations for improvements, such as:

• Introduce Market Maker mechanism

In international FX market, Market makers are commercial banks with huge capital reserve and market faith. Market maker would provide market participants with continues Bid-Ask quotes, and trading with their own capital at risk. The other market participants normally obtain from market maker, and trade with them. Market maker in FX market has essentially the same functions as market makers in the securities market, provide liquidity. Liquidity is improved from three aspects, (1) Market maker provides continues bid-ask quotes, and also takes other market participants' orders at their own price. This reduced waiting time of the market participant, thus the time cost. (2) Completive bids between market makers would attract markets participants with the fair prices, and more participants imply greater liquidity. (3) Market maker stimulates the market through trading on credit. Commercial banks act as market maker not just simply sitting on huge currencies positions and waiting for participants asking for quotes, they have to keep a dynamically managed currency inventories.

• Improve the market-maker mechanism in FX

(1) Lift the FX quota on FX market maker

Under china's current capital control practice, FX trading follows a need base. Interbank FX market is established to help settle FX positions entered under the FX quota system. Therefore, the commercial banks' motives are simply comply with SAFE (State Administration of Foreign exchange)'s regulation, rather than for their own profits. However, the market making activities should be based on forecast of market movements and profit driven. From the global perspective, financial FX trading is several times larger than FX traded for international trades and direct interments. This would require the money authorities (SAFE, central banks) to relieve or lift the current quota system in FX market, and allow market makers take positions as they predict the market, otherwise the market makers would not be fully functional.

(2) Gradually grant market maker right to quote

Banks being able to manage their own FX inventories based on their view of the market, and has autonomy in setting FX quotes are the two preliminary requirements for efficient market making. In 2005 Sep, china's central bank has increased the allowed volatility in non US currencies pairs, lifted bars on bid-ask spread for non US currencies, improved the way USD was quoted, increased the possible bid-ask spread. When china's FX markets matures, commercial banks who act as market makers should be grant autonomy in quoting the price.

• Develop the off-shore futures market and derivatives.

To truly improve FX flexibility, china should minimize intervention on its pegging system, utilized the market rather than policy to stabilize the currency system.
From the global experience, free FX system fueled the development in FX market in the 1970s, and brought with it, forward currency trading, currency swap, and other derivatives such as currency futures and options.

In those advanced markets, even though the volatilities are huge, but with the diversity and availability of hedging instruments, those volatilities are isolated from the real economy. Money authorities should be refrained from worrying about the FX risk and focus more on the real economy. So to avoid the possible impact comes with the transformation of FX mechanism, domestic FX market should be improved first, more currencies pairs should be made available to diversify FX risk. And corporations and financial institutions should be equipped with risk management tools to hedge their FX exposure.

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