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Testing the Real Interest Parity Hypothesis in Six Developed Countries

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Abstract

In this paper, we conduct unit-root tests (including ADF, PP, KPSS and DF-GLS tests) on the ex post real interest rates in six developed countries (Canada, France, Japan, Italy, Singapore, the UK against the US). We also use real interest rate differential (RID) to examine whether real interest rate parity holds in these countries. Our result supports that real interest rates are mean reverting and the real interest parity (RIP) hypothesis holds in the majority of the chosen countries.

Keywords: Interest Rate Differential, Interest Rate Parity, Unit Root Test.

1. Introduction

Since 1980s, the most significant change of the financial market has been the gradual integration of financial market with the development of globalization. Financial policies of every country are towards internationalization and liberalization. Recently, the flow of international capital has become more frequent in terms of quality and quantity. In the long term, the inflow and outflow of international capital will have a significant impact on direct financial investment and the growth of the economics of the domestic country; however, in the short term, it will cause the instability of exchange rate, the price of security, interest rates and the demand for domestic currency. To pursue a more efficient capital market, financial policies of each country gradually relax the restriction of capital flows between nations. The floating of the currency of a nation will directly affect its exports and imports, thereby affecting its balance of payment and the price of commodity.

However, not only the exchange rate will affect economic activities, but the interest rate is also another important factor. Interest rate will affect a country's investments, savings, the demand for domestic currency, and so on. It will also affect the price of commodity and the balance of payment. Each country can take advantage of its monetary policy to change the interest rates, thereby having impacts on the economy of this country. With the integration of financial economics and the frequent flow of capital, each country however could not employ an independent monetary policy.

Purchasing power parity (PPP) and uncovered interest parity (UIP) can be used to investigate the cross-border economic activities. Those two hypotheses are the basics of monetary theories. Combining the PPP, UIP and the Fisher equation, one can obtain the real interest rate parity (RIP) that is an important indicator of measuring international capital flow. The RIP argues that if every investor expects rationally to make his financial decision, and there are no barriers among global markets, the real interest rate of each country must be the same. If the RIP hypothesis fails to hold, it implies that policy makers can make monetary policies independently.

In this paper, we test mean reversion in the ex post real interest rates in six developed countries (Canada, France, Japan, Italy, Singapore, the UK vis-a-vis the US). We employ real interest rate differential (RID) to examine whether real interest rate parity holds in these countries. We apply unit root tests including ADF, PP, KPSS and DF-GLS tests. Our result supports that real interest rates are mean reverting and the real interest parity (RIP) hypothesis holds in the majority of the chosen countries.

The remainder of the paper is organised as follows. Section 2 reviews relevant literature. Section 3 develops testable hypotheses, and Section 4 introduces the methodology. Section 5 presents the data, and Section 6 provides the empirical results. Section 7 concludes.

2. Related Literature

Over the last 30 years, the majority of the world's governments have undertaken deregulation and liberalisation of their financial markets in order to stimulate a greater degree of integration between their markets and those of the rest of the world. Market integration allows a country to raise its standard of living and leads to greater capital flows by facilitating commodity and financial arbitrage, which in turn eliminates the difference between these countries' real rates of return. An implication of financial market integration, however, is that the greater a country is integrated, the less control domestic monetary authorities have in influencing and pursuing stabilisation policies since if real rates are equalised across countries, the ability to which the authorities can influence their countries' real interest rate is limited to the extent to which they can influence the world rate.

A vast amount of research has been conducted on the topic of whether or not real interest rates are mean reverting and the general conclusion depends on the tests the researchers use. Studies of this hypothesis usually begin with the Fisher relation, which states that the nominal interest rate adjusts to changes in the expected inflation rate and the other key focus is on real interest parity (RIP) condition which provides direct evidence on whether or not the process of financial deregulation has led to greater market integration and capital mobility and therefore limiting monetary authorities' impact on the stabilisation of policies. For instance, Mishkin (1984), Goodwin and Grennes (1994), Chung and Crowder (2004) test RIP by examining the hypothesis that ex-ante real interest rates are equal across countries whereas Cumby and Obstfeld (1984) test RIP by attempting to determine where there is any correspondence between nominal interest rates and inflation differentials. Cumby and Mishkin (1986) find a significantly positive international linkage of real interest rates, but it is less than complete, i.e., less than one-to-one relationship and it thus implies that monetary policy is able to influence the economy. Moosa and Bhatti (1997) test the degree of integration between Asian countries by examining Uncovered Interest Parity (UIP) and ex ante Purchasing Power Parity (PPP) and they find strong support of validity of UIP and ex–ante PPP in almost all cases.

Moosa and Bhatti (1996) present evidence of mean reversion in ex ante real interest rates and their differentials using the Philips-Ouliaris (1990) statistic, the Sims (1988) Bayesian test and the variance ratio test. The conventional tests such as the Dickey-Fuller (1979) statistic, *F*-statistic, the Box-Pierce (1970) and the Ljung-Box (1978), are unable to distinguish between what is a near random walk and what is a true random walk and thus the results may be biased. Another reason as to why conventional tests fail to support real interest equalisation across countries is that they ignore transaction costs (Goodwin and Grennes, 1994). Goodwin and Grennes (1994, p.118) note that "the non-synchronous variations of individual interest rates in response to local financial conditions may have led to the incorrect rejection of mean reversion even though the market in question is in fact integrated and efficient". In response to this finding, they propose an alternative model to allow for non-synchronous events and conclude that the evidence is much stronger than commonly found.

Kinal and Lahiri (1988) propose a model to determine the expected real interest rate in which the effect of price expectations is considered and they find evidence that between the period 1953-1985 the price forecasts derived are unbiased. Given the rational expectations theory the actual real interest rate is equal to the ex-ante real interest rate plus an error term, their model postulates that the random forecasting errors are not confound to the variation of the ex-ante interest rate.

3. Hypothesis Development

The real interest parity (RIP) hypothesis postulates that the ex-ante real interest rate is constant and the nominal interest rate differential is exactly equal to the amount of the inflation rate differential. If this is the case, then financial markets will be integrated and capital will be free to flow in and out of countries. Our null hypothesis is thus that the real interest rate parity holds for each country.

Moosa and Bhatti (1996) argue that the RIP requires the following assumptions: the validity of covered interest rate parity (efficiency of domestic and foreign capital markets), purchasing power parity (efficiency of commodity and financial markets) and the unbiasedness of the forward rate as a forecaster of the future spot rate, the mathematical equations of which are as follows:

$$f_t - s_t = i_t - i_t^*, \tag{1}$$

$$s_{t+1}^e - s_t = \triangle p_{t+1}^e - \triangle p_{t+1}^{*e}, \tag{2}$$

$$s_{t+1}^e = f_t, \tag{3}$$

where s_t is the logarithm of the spot exchange rate, f_t is the logarithm of the forward exchange rate, i_t (i_t^*) is the domestic (foreign) nominal interest rate, s_{t+1}^e is the logarithm expected interest rate at time *t+1*, s_t is the logarithm of the spot exchange rate, and Δp_{t+1}^e (Δp_{t+1}^{*e}) is the inflation rate that can be calculated as the first order difference of the ex-ante logarithm of domestic (foreign) consumer price index.

From (1) and (2) , we can obtain

$$s_{t+1}^e - s_t = i_t - i_t^*, \tag{4}$$

which is the uncovered interest parity (UIP) condition. Substitute (2) into (4) yielding

$$\Delta p_{t+1}^e - \Delta p_{t+1}^{*e} = i_t - i_t^*, \tag{5}$$

The RIP hypothesis is not only based on UIP condition and ex ante PPP, and more importantly, it is based on the Fisher effect. The Fisher effect implies that the nominal interest rate is equal to the sum of the real interest rate and the inflation rate.

This hypothesis is thus given as

$$i_t = r_{t+1}^e + \Delta p_{t+1}^e, \text{ and} \tag{6}$$

$$i_t = r_{t+1} + \Delta p_{t+1}, \tag{7}$$

where r_{t+1}^e is the ex-ante real interest rate. Equations (6) and (7) suggest that the Fisher condition is valid both in the domestic country and foreign countries. Rearranging (5) yields the real interest parity condition:

$$r_{t+1}^e = r_{t+1}^{*e}. \tag{8}$$

If ex ante real interest rate is constant between different countries, the ex-ante interest rate differential is mean reverting and that real interest rate parity holds. Therefore, assuming rational expectations:

$$r_{t+1} = r_{t+1}^{e} + \varepsilon_{t+1}, \tag{9}$$

$$r_{t+1}^{*} = r_{t+1}^{*e} + \varepsilon_{t+1}^{*}, \tag{10}$$

where $\varepsilon_{t+1} \sim I(0)$, $\varepsilon_{t+1}^{*} \sim I(0)$, and $\varepsilon_{t+1} = \Delta p_{t+1}^{e} - \Delta p_{t+1}$, and $\varepsilon_{t+1} = \Delta p_{t+1}^{e} - \Delta p_{t+1}$, we can obtain

$$r_{t+1} - r_{t+1}^{*} = rid_{t+1} = \xi_{t+1}, \tag{11}$$

where $\xi_{t+1} = \varepsilon_{t+1} - \varepsilon_{t+1}^{*}$, $\xi_{t+1} \sim I(0)$ and *rid* stands for real interest differential between domestic country and the foreign country. Ex post RIP also implies ex ante RIP under the assumption of rational expectations. The long-run RIP holds in the case that the ex post real interest rate differential is zero mean stationary.

4. Methodology

Our test model is specified as:

$$rid_{t} = \gamma_{0} + \gamma_{1} rid_{t-1} + \varepsilon_{t}. \tag{12}$$

In our model, if *rid* is mean reverting in the long run, the RIP hypothesis holds in the long-run equilibrium. Our objective is thus concentrated on performing unit root tests on *rid*.

We use Augmented Dickey-Fuller (ADF) test, Phillips-Perron test, and the KPSS test, which are introduced one by one below.

4.1. ADF Test

The augmented Dickey–Fuller test (ADF) is a test for a unit root in a time series data. It is an augmented version of the Dickey–Fuller test. ADF is the conventional method for testing unit-root. The ADF model is stated as follows:

$$\Delta rid_{t} = \alpha + \beta t + (\rho - 1) rid_{t-1} + \sum_{i=1}^{k-1} \theta_{i} \Delta rid_{t-1} + \varepsilon_{t}, \tag{13}$$

where α is the drift, *t* is the deterministic trend independent variable, *k* is the lag length, and ε_{t} is the white noise. The null hypothesis of the test is that: $\rho - 1 = 0$, which implies that the series is a random walk.

The first alternative hypothesis is that: $\rho - 1 < 0$ and $\alpha = 0$, which implies that the series is zero mean stationary and the RIP holds. The second alternative hypothesis is that: $\rho - 1 < 0$ and $\alpha \neq 0$, which implies that the series converges to the mean value that is not equal to zero. The RIP hypothesis does not hold probably due to country specific risk premium.

If *rid* converged to the white noise process, it will be consistent with the RIP hypothesis, since the shocks will gradually have no effect.

An important practical issue of the ADF test is the specification of the lag length *p*. If *p* is too small, serial correlation in the errors will bias the test. If *p* is too large, the power of the test will suffer. Ng and Perron (1995) suggest a process to select a lag to provide relative stability in the data by setting an upper bound and then estimating the upper bound to test for significance.

The ADF test is a conventional and popular methodology to test the unit root. However, it is flawed when applied in these three situations: small samples, structural breaks, and near random walk. ADF is well-known of its low power to detect the difference between the unit root and near random walk, especially when the sample size is small. On the other hand, the standard test will be biased if there is a structural change. Perron (1989) shows that the power of this test to reject the null hypothesis of a unit root, when the underlying series is stationary with a break in either its mean or trend, falls as the size of the break increases. By contrast, Franses and Haldrup (1994) show that the size of the ADF test was sensitive to the presence of outliers. In particular, they show that at a nominal 5% significance level, the empirical size of the ADF test increases with an increase in either the frequency of outliers, or the size of the outlier, concluding that the implications of this type of data irregularities will tend to produce spurious stationarity.

4.2. Phillips-Perron Unit Root Test

The Phillips-Perron (PP) unit root tests differ from the ADF test mainly in how it deals with serial correlation and heteroskedasticity in the errors. In particular, where the ADF test use a parametric autoregression to approximate the ARMA structure of the errors in the test regression, the PP test ignores any serial correlation in the test regression.

De Jong et al. (1990) shows that the Dickey–Fuller test statistics have been criticised for their low power, especially in distinguishing between unit roots and near unit roots and in small sample data. On the other hand, the Phillips–Perron (PP, 1988) test is more robust to serial correlation, time dependent heteroscedasticity and regime changes (Moosa and Bhatti, 1997).

The calculation of Phillips-Perron test is based on the regression

$$\hat{u}_t = \hat{a}\hat{u}_{t-1} + \hat{k}_t . \tag{14}$$

Then the $\hat{Z}_a$ statistic, a transformation of the standardised estimator $T(\hat{a}-1)$, is given by:

$$\hat{Z}_a = T(\hat{a}-1) - (1/2)(s_{Tl}^2 - s_k^2)\left(T^{-2}\sum_{2}^{T}\hat{u}_{t-1}^2\right)^{-1}, \tag{15}$$

where T is the sample size, and the consistent estimates s_k^2 and s_{T1}^2 are given by

$$s_k^2 = T^{-1}\sum_{1}^{T}\hat{k}_t^2 \text{, and} \tag{16}$$

$$s_{T1}^2 = T^{-1}\sum_{1}^{T}\hat{k}_t^2 + 2T^{-1}\sum_{s=1}^{l} w_{sl}^2 \sum_{t=s+1}^{T}\hat{k}_t\hat{k}_{t-s}, \tag{17}$$

for some choice of window such as $w_{sl} = 1 - s/(l+1)$.

The $\hat{Z}_t$ statistic, a transformation of the regression t statistic, is given by:

$$\hat{Z}_t = \left(\sum_{2}^{T}\hat{u}_{t-1}^2\right)^{1/2}(\hat{a}-1)/s_{T1} - (1/2)(s_{T1}^2 - s_k^2)\left[s_{Tl}\left(T^{-2}\sum_{2}^{T}\hat{u}_{t-1}^2\right)^{1/2}\right]^{-1}. \tag{18}$$

These two statistics are derived using an estimate s_{T1}^2, which is based on the residuals $\hat{k}_t$ from the autoregression of $\hat{u}_t$ on $\hat{u}_{t-1}$. s_k^2 and s_{T1}^2 help to develop this tests for unit roots which could be employed under very general conditions.

Under the null hypothesis that π = 0, the PP Z_t and Z_a statistics have the same asymptotic distributions as the ADF *t*-statistic and normalised bias statistics. One advantage of the PP tests over the ADF test is that the PP test is robust to general forms of heteroskedasticity in the error term. Another advantage is that the user does not have to specify a lag length for the test regression.

The ADF and PP tests have very low power against I(0) alternatives that are closer to being I(1). That is, unit root tests cannot distinguish highly persistent stationary processes from nonstationary processes very well. Also, the power of unit root tests diminish as deterministic terms are added to the test regressions. That is, tests that include a constant and trend in the test regression have less power than tests that only include a constant in the test regression. For achieving maximum power against near random walk, recent tests proposed by Elliot, Rothenberg and Stock (1996) and Ng and Perron (2001) can be used.

4.3. KPSS Test

Kwiatkowski, Phillips, Schmidt and Shin (KPSS, 1992) test use the LM statistic to test the unit root. The times series rid_t is the sum of the deterministic trend, a random walk and the error term. The KPSS model is as follows:

$$v = T^{-2}\sum_{1}^{T}\frac{s_t^2}{\sigma_k^2}, \quad (19)$$

$$s_t = \sum_{i=1}^{t} e_i, \quad t = 1,\ldots,T \quad (20)$$

where e_i is the regression coefficient of rid_t on intercept and time t, σ_k^2 is the variance of rid_t in long period, k is the number of lagged periods, T is the number of the sample, and v is the asymptotic distribution. The null hypothesis is that rid_t is level stationary and stationary around a linear trend and the alternative hypothesis is that rid_t has a unit root. If v is larger than the significant level, we will reject the null hypothesis and conclude that rid_t has a unit root.

The advantage of the KPSS is that to some extent KPSS alleviates the problem that is present with the ADF test. Kwiatkowski, Phillips, Schmidt and Shin (1992) argue that KPSS test can distinguish a series that appears to be stationary, series that appear to have a unit root, and series for which the data are not sufficiently informative to be sure whether they are stationary or integrated.

Perron (1989) and Chen (2002) investigate the behaviour of the KPSS test in the presence of permanent changes in the intercept and/or trend of a stationary series. They find that the KPSS test has the power to reject the null hypothesis of level and trend stationarity of a series in the presence of these breaks.

4.4. DF-GLS Test

Elliot, Rothenberg and Stock (1996) propose a modified Dickey-Fully test (the DF-GLS test). This unit root test is more powerful than the ADF test. Its regression function is:

$$\Delta X_t^d = a_0 X_{t-1}^d + a_1 \Delta X_{t-1}^d + \cdots + a_P \Delta X_{t-p}^d + \varepsilon_t, \quad (21)$$

where ΔX_t^d is the detrended series. When DF-GLS only contain the intercept, the t value is the same as the ADF test, and its critical value is as per the ADF test. When DF-GLS test contains both trend and intercept, its distribution is different from the ADF test, and its critical value is as per the ERS test.

KPSS and DF-GLS are both recently new tests intending to deal with the flaws that ADF and PP tests have. However, as these new tests probably have remedied the problems the ADF and PP tests have while some new problems appear. Briefly speaking, up to now, there is not such an advanced unit root test which is easy and convenience to solve all the problems.

5. Data

We use the data for the following developed countries: Canada, France, Japan, Italy, Singapore, the UK, and the US which is a benchmark country. The sample data consists of quarterly observations on Consumer Prices Index (CPI), and interest rate. The data are sourced from the IMF's International Financial Statistics (IFS). We choose the sample period 1980Q2-2009Q1 because after 1980s the world financial markets became relatively more integrated. There are two kinds of interest rates for us to choose from: 3-month Treasury bill and 3-month deposit rate. We choose 3-month Treasury bill rate (percent per annum) for Canada, Italy, France, UK, Singapore, and the US; and we choose 3-month deposit rate for Japan. In regards to the choice of maturity, as stated by the liquidity premium theory in which investors tend to prefer bonds with short-term maturities rather than bonds with longer-term maturities since they tend to bear less interest-rate risk.

There are three steps required to get the real interest rate and the real interest rate differential against the US. First, we calculate the inflation rate. We transfer the data by the following equation:

$$\pi_{t+1} = (CPI_{t+1} - CPI_t) / CPI_t \times 100\,. \tag{22}$$

Second, as the interest rates in the database are nominal interest rates, we use the Fisher equation (the nominal interest rate minus the expected interest rate) to get the real interest rate:

$$r_t = i_t - \pi^e_{t+k}\,, \tag{23}$$

Where r_t is the real interest rate in spot *t*, period *k*; and it is nominal interest rate in the spot *t*, period *k*; π^e_{t+k} is the expected inflation rate from spot *t* to spot $t+k$. The ex post real interest rate is thus the nominal interest rate minus the expected inflation rate. Third, we use the following equation to obtain the real interest rate differential (RID):

$$RID_t = r_t - r^*_t\,, \tag{24}$$

where RID_t is the real interest rate differential against the US at spot *t*, r_t is the real interest rate of domestic country in spot *t*, and r^*_t is the real interest rate of the US.

The condition of real interest parity follows:

$$r(t) = \alpha + \beta r^*(t) + \varepsilon\,, \tag{25}$$

where r_t is the real interest rate of domestic country, r^*_t is the real interest rate of the US. On the one hand, if $\alpha = 0$, $\beta = 1$ and $\varepsilon \sim I(0)$, the RIP condition holds. On the other hand, if $\varepsilon \sim I(0)$, there exists a cointegrating relationship between the domestic country and the US, in other words, there is a stable relationship between them in the long run, and the RIP condition will be converged in the future.

The time-series plot for the real interest rates and real interest differential series can be found in Figure 1 and Figure 2, respectively.

Figure 1: Real Interest rate for G6 and the US

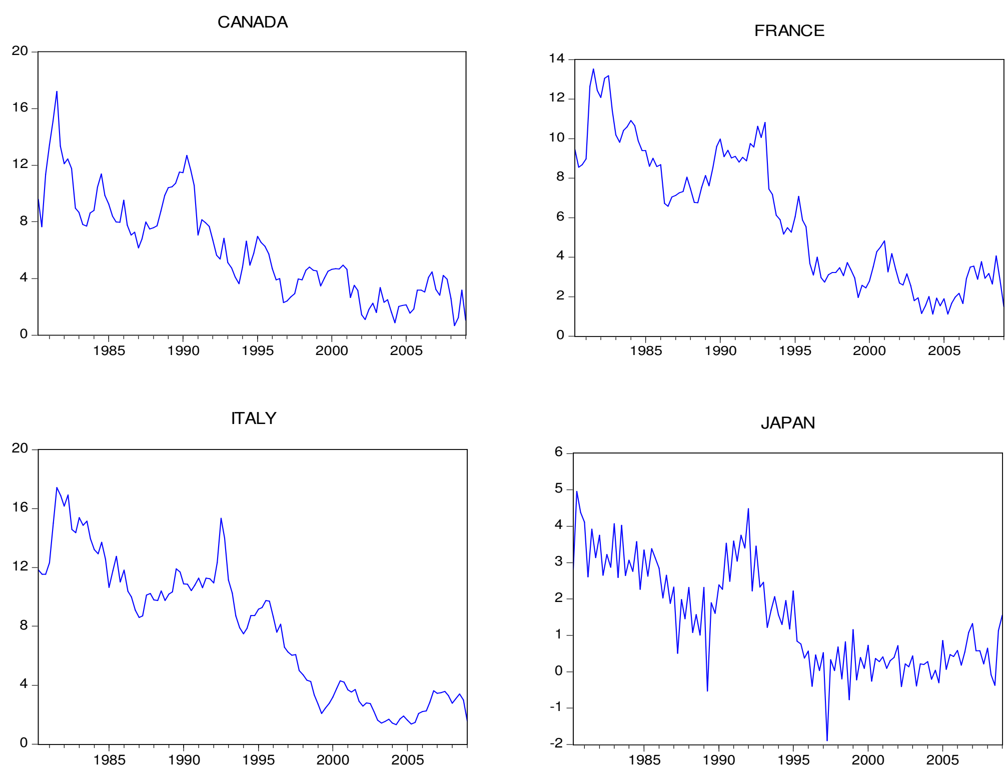


Figure 1: Real Interest rate for G6 and the US - continued

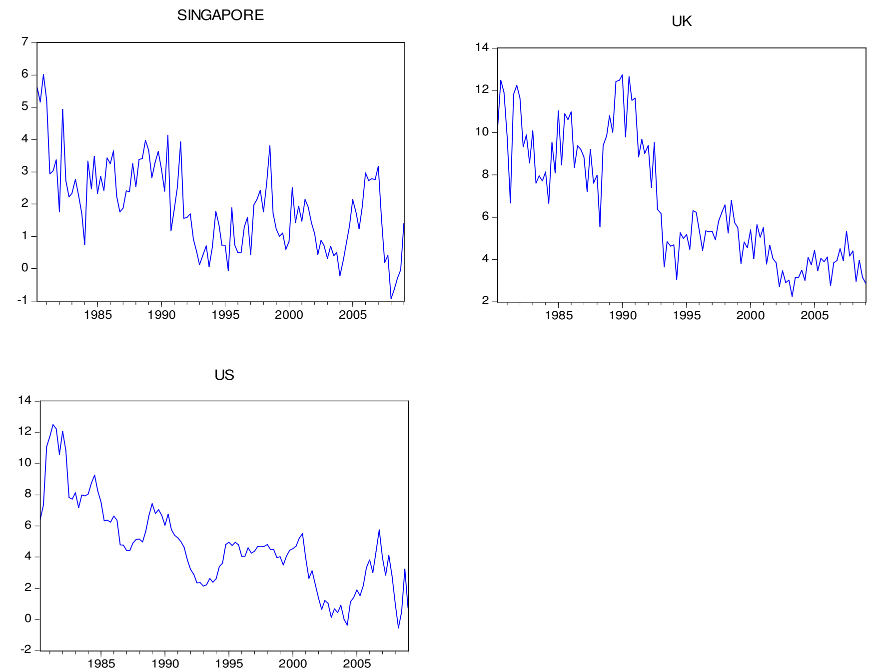
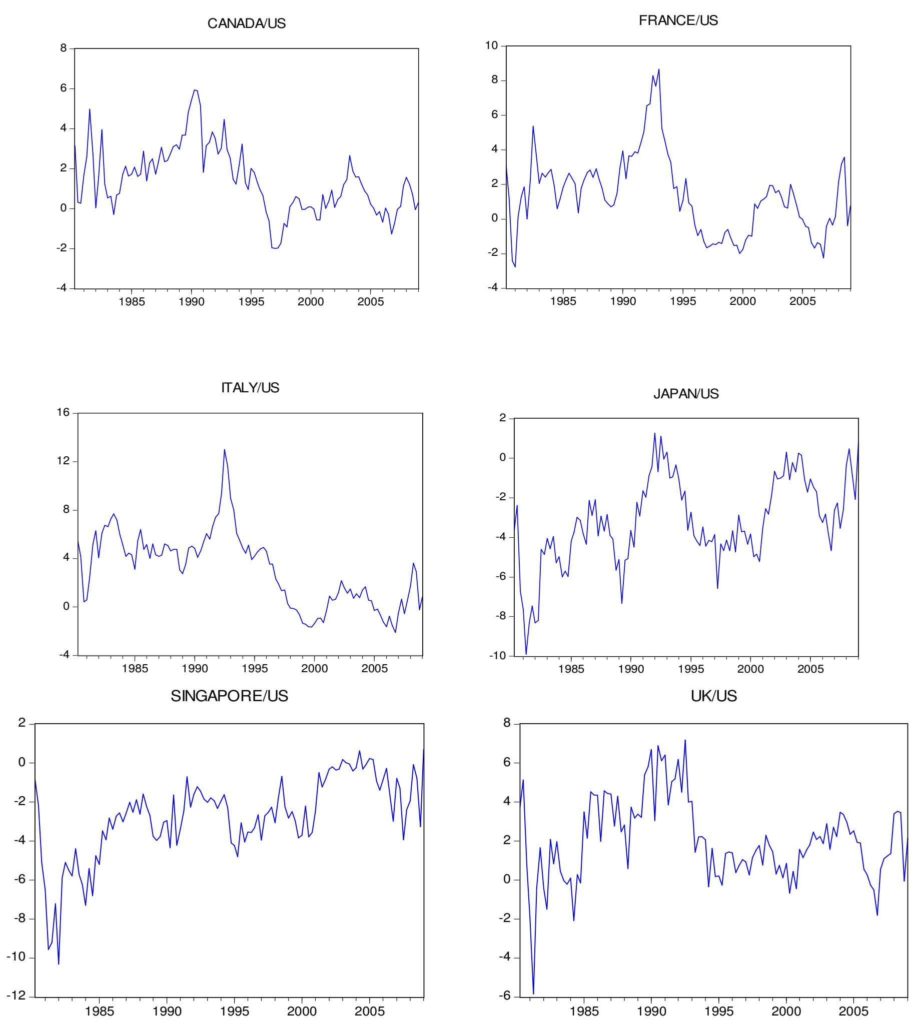


Figure 2: Real Interest Rate Differential of G6 against the US



6. Empirical Findings

The section provides the empirical testing results based on the testing methods we introduced in the previous section.

We employ conventional unit root tests: ADF, PP, KPSS to test real interest rate and real interest rate differential in order to examine whether there is mean reversion in real interest rates and whether the RIP hypothesis holds. Furthermore, we use a more powerful unit root test, DF-GLS test. As the result of ADF and DF-GLS are all very sensitive to the number of lags chosen. The optimal lag is given by the minimum value of the Schwarz Information Criterion for ADF and DF-GLS. On the other hand, the KPSS and PP tests are sensitive to the number of bandwidth, and therefore we choose the Newey-West bandwidth as the optimal bandwidth.

The null hypothesis of the ADF, PP, DF-GLS test is that the time series has a unit root (I(1)), the alternative hypothesis of the ADF, PP, DF-GLS test is that the time series is stationary (I(0)). The null hypothesis of the KPSS test is that the time series is stationary (I(0)), the alternative hypothesis of KPSS test is that the time series has a unit root (I(1)).

Table 1 to Table 4 show the testing results with constant only and both the trend and constant. Table 1 demonstrates that the ADF test does not support I(0) for France, Italy and Japan while supports I(0) for Canada, Singapore, the UK and the US. The PP test have less power than the ADF test, and it does not support I(0) for France and Italy, while supports I(0) for Japan, Canada, Singapore, the UK and the US. By contrast, the KPSS test has more power than the ADF and PP tests and it shows that the series of all the countries are stationary.

Table 1: ADF, PP, KPSS Tests for the Real Interest Rate of G6 and the US in Level

R	ADF		PP		KPSS	
	Constant	Trend	Constant	Trend	Constant	Trend
CANADA	-1.64 (0)	-3.67*(0)	-1.63 (3)	-3.81*(2)	1.11*(9)	0.08 (7)
FRANCE	-1.19 (0)	-3.07 (0)	-1.17(2)	-3.20 (4)	1.09*(9)	0.09 (8)
ITALY	-0.75 (0)	-2.90 (0)	-0.85 (1)	-3.11(2)	1.13*(9)	0.09(8)
JAPAN	-1.90 (4)	-2.09(4)	-4.17*(10)	-8.17*(9)	0.99*(9)	0.11 (9)
SINGAPORE	-3.59* (1)	-5.51*(0)	-4.51*(6)	-5.55*(6)	0.87*(8)	0.10 (7)
UK	-1.69 (8)	-3.57*(8)	-2.48 (10)	-5.67*(10)	1.06*(9)	0.08(8)
US	-1.56 (0)	-4.86*(5)	-1.67(4)	-3.67(6)*	0.97*(9)	0.12(8)

Critical Value	Intercept 5%	Trend and intercept 5%
ADF	-2.89	-3.45
PP	-2.89	-3.45
KPSS	0.46	0.15

Note: We use ADF, PP, KPSS to test Canada, France, Italy, Japan, Singapore, the UK, the US in level. "Constant" denotes the model with an intercept term, and "trend" denotes the model with both the intercept and trend terms. * indicates rejection of the null hypothesis at the 5% significant level. The number in parentheses in the ADF is the lag number, and it is generated automatically based on the Schwarz Information Criterion. The number in the brackets in the PP and KPSS is the Newey-West bandwith and it is based on the Bartlett Kernel method.

Table 2 shows that the series become stationary for all the countries after the first difference. The ADF test shows that the real interest rates of Canada, Singapore, the UK, and the US are I(0), and of France, Italy, and Japan are I(1). The PP test shows that the real interest rates of Canada, Singapore, Japan, the UK, and the US are I(0) and of France and Italy are I(1). The KPSS test shows that the real interest rate of all the countries are I(0).

Table 2: ADF, PP, KPSS Tests for the Real Interest Rate (First Difference) of G6 and the US in Level

D(R)	ADF		PP		KPSS	
	Constant	Trend	Constant	Trend	Constant	Trend
CANADA	-10.48* (0)	-10.44*(0)	-10.48*(2)	-10.44*(2)	0.03 (6)	0.03 (6)
FRANCE	-11.01* (0)	-10.96*(0)	-11.02*(3)	-10.97*(3)	0.04 (1)	0.04 (1)
ITALY	-8.89* (0)	-8.86*(0)	-8.82*(3)	-8.80*(2)	0.06 (2)	0.05 (2)
JAPAN	-5.24* (3)	-5.32*(3)	-28.91*(5)	-29.36*(5)	0.12 (11)	0.09(11)
SINGAPORE	-15.28* (0)	-15.25*(0)	-15.82*(2)	-15.80*(2)	0.06(1)	0.02 (1)
UK	-4.93* (9)	-4.84*(9)	-19.93*(7)	-19.87*(7)	0.04 (10)	0.04 (10)
US	-9.59* (1)	-9.54*(1)	-9.52*(3)	-9.47*(3)	0.04 (4)	0.04(4)

Critical Value	Intercept 5%	Trend and intercept 5%
ADF	-2.89	-3.45
PP	-2.89	-3.45
KPSS	0.46	0.15

Note: We use ADF, PP, KPSS to test Canada, France, Italy, Japan, Singapore, the UK, the US in first difference. "Constant" denotes the model with an intercept term, and "trend" denotes the model with both the intercept and trend terms. * indicates rejection of the null hypothesis at the 5% singnificant level. The number in parentheses in the ADF is the lag number, and it is generated automatically based on the Schwarz Information Criterion. The number in the brackets in the PP and KPSS is the Newey-West bandwith and it is based on the Bartlett Kernel method.

Next, we examine the unit root of real interest rate differential and the results are presented in Table 3 and Table 4. First of all, the ADF test shows that the RID of Canada, Japan and Singapore all reject the null hypothesis which implies that they are stationary (I(0)). The test on the RID of France, Italy and the UK cannot reject the null hypothesis that they have a unit root (I(1)).

Table 3: ADF, PP, KPSS Tests for the Real Interest Rate Differential of G6 against the US in Level

RID	ADF		PP		KPSS	
	Constant	Trend	Constant	Trend	Constant	Trend
CANADA	-3.20*(0)	-3.59*(0)	-3.01*(3)	-3.47*(2)	0.56*(8)	0.12 (8)
FRANCE	-2.70 (0)	-2.81 (0)	-2.77 (4)	-2.90 (4)	0.12 (8)	0.11 (8)
ITALY	-1.93 (0)	-2.56 (0)	-1.93 (0)	-2.56 (0)	0.75*(9)	0.13 (8)
JAPAN	-3.74*(4)	-4.03*(4)	-2.93*(8)	-3.98*(8)	0.53*(8)	0.09 (8)
SINGAPORE	-2.34 (1)	-4.18*(1)	-3.32*(7)	-5.74*(7)	0.87*(8)	0.09 (7)
UK	-2.43 (8)	-2.63(8)	-4.88*(8)	-4.86*(8)	0.17 (8)	0.14 (8)

Critical Value	Intercept 5%	Trend and intercept 5%
ADF	-2.89	-3.45
PP	2.89	-3.45
KPSS	0.46	0.15

Note: We use ADF, PP, KPSS to test the real interest rate differetial of Canada, France, Italy, Japan, Singapore and the UK against the US in level. "Constant" denotes the model with an intercept term, and "trend" denotes the model with both the intercept and trend terms. * indicates rejection of the null hypothesis at the 5% singnificant level. The number in parentheses in the ADF is the lag number, and it is generated automatically based on the Schwarz Information Criterion. The number in the brackets in the PP and KPSS is the Newey-West bandwith and it is based on the Bartlett Kernel method.

Table 4: DF-GLS Test for the Real Interest Rate Differetial of G6 against the US in Level

RID	DF-GLS	
	Constant	Trend
CANADA	-2.47 *(0)	-3.60*(0)
FRANCE	-2.34 *(0)	-2.83 (0)
ITALY	-1.58 (0)	-2.53 (0)
JAPAN	-3.69 *(4)	-4.20*(4)
SINGAPORE	-1.98 *(1)	-2.38 (1)
UK	-2.09 *(8)	-2.75 (8)

Critical Value	Intercept 5%	Trend and intercept 5%
DF-GLS	-1.94	-3.02

Note: We use DF-GLS to test the real interest rate differetial of Canada, France, Italy, Japan, Singapore and the UK against the US in level. "Constant" denotes the model with an intercept term, and "trend" denotes the model with both the intercept and trend terms. * indicates rejection of the null hypothesis at the 5% singnificant level. The number in parentheses in the DF–GLS is the lag number, and it is generated automatically based on Schwarz Information Criterion.

Second, the PP test shows that the null hypothesis is rejected for Canada, Japan, Singapore and the UK, but cannot be rejected for France and Italy.

Third, the KPSS test shows that all the RID of the countries are stationarity (I(0)). Finally we apply a more powerful test, DF-GLS test (presented in table 4) and find that for Canada, France, Japan, Singapore and the UK, the test reject the null hypothesis that are stationary (I(0)) except for Italy.

Although the ADF, PP, KPSS and DF-GLS tests are all conventional unit root tests, they are all based on an independent equation. When a near unit root is present within the data, the conventional unit root tests have low power and cannot distinguish between a unit root and a near unit root. These conventional unit root tests are based on the condition that the sample is infinite. Our sample is finite and as a result the conventional unit root tests tend not to work very well. In short, among these four unit root tests, the ADF is the worst, and the PP test performs slightly better. However the KPSS and DF-GLS test have the ability to distinguish a near unit root from a unit root and therefore produce more accurate results.

7. Summary and Concluding Remarks

In this paper we conduct four kinds of unit root tests: ADF, PP, KPSS and DF-GLS on the real interest rates in six developed countries: namely, Canada, France, Japan, Italy, Singapore and the UK vis-a-vis the US. Both the ADF and PP tests are weak when dealing with small sample with near random walk. Similar to the finding of Moosa and Bhatti (1996), when we use low power ADF and PP tests, our result show that the real interest rate and RID of only some of the G6 countries are stationary. In contrast, when we use more powerful KPSS and DF-GLS tests, we find that the real interest rate and RID of most of the G6 countries are stationary. Our result supports that real interest rates are mean reverting and the real interest parity (RIP) hypothesis holds in the majority of the chosen countries.

For future research, a possible venue is to use the variance ratio test on the real interest rate and RID. In addition, a seemingly unrelated regression (SUR) can be used to estimate the system of the equations, as Wu and Zhang (1996) argue that the SUR is more efficient than the single equation estimation because the SUR fully exploits the information in cross-country correlations and the SUR takes advantage of cross-equation parameter restriction.

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References
[1] Box, G.E.P. and D.A. Pierce, 1970, "Distribution of residual autocorrelation in autoregressive integrated moving average time series models", *Journal of the American Statistical Association*, 65, pp. 1509-1526.
[2] Chen, M.Y., 2002, "Testing stationarity against unit roots and structural changes", *Applied Economics Letters* 9, pp. 459-464.
[3] Chung, S.Y. and W.J. Crowder, 2004, "Why are real interest rates not equalized internationally", *Southern Economic Journal*, 71, pp. 441-458.
[4] Cumby R.E. and M. Obstfeld, 1984, "International interest-rate and price-level linkages under flexible exchange rates: A review of recent evidence", in FO Bilson, R Marston (Eds.), "Exchange Rate: Theory and Practice," NBER books, National Bureau of Economic Research, Inc.
[5] Cumby, R.E. and F.S. Mishkin, 1986, "The international linkage of real interest rates: The European-US connection", *Journal of International Money and Finance*, 5, pp. 5-23.
[6] Dickey, D.A., and W.A. Fuller, 1979, "Distribution of the estimators for autoregressive time series with a unit root", *Journal of the American Statistical Association*, 74, pp. 427-431.
[7] DeJong, D.N, J.C Nankervis and N.E Savin, 1990, "The power problems of unit root tests in time series with autoregressive errors", *Working Paper*, University of Iowa.
[8] Elliot G., T.J. Rothenberg and J.H. Stock, 1996, "Efficient tests for an autoregressive unit root", *Econometrica*, 64, pp. 813-836.
[9] Franses, P.H., and N. Haldrup, 1994, "The effects of additive outliers on tests for unit roots and cointegration", *Journal of Business and Economic Statistic*, 12, pp. 471-478.
[10] Goodwin, B.K. and T.J. Grennes, 1994, "Real interest rate equalization and the integration of international financial markets", *Journal of International Money and Finance*, 13, pp. 107-124.
[11] Kinal, T., and K. Lahiri, 1988, "A model for ex ante real interest rates and derived inflation forecasts", *Journal of the American Statistical Association*, 83, pp. 665-673.
[12] Kwiatkowski, D., P.C.B. Phillips and P. Schmidt, 1992, "Testing the null hypothesis of stationarity against the alternative of a unit root", *Journal of Econometrics*, 54, pp. 159–178.
[13] Ljung, G.M. and G.E.P Box, 1978, "On a measure of lack of fit in time series models", *Biometrika*, 65, pp. 297-303.
[14] Mishkin, F.S., 1984, "The real interest rate: A multi-country empirical study", *Canadian Journal of Economics*, 17, pp. 283-311.
[15] Moosa, I.A. and R.H. Bhatti, 1996, "Some evidence on mean reversion in ex ante real interest rate", *Scottish Journal of Political Economy*, 43, pp. 177-191.
[16] Moosa, I.A. and R.H. Bhatti, 1997, "Are Asian markets integrated? Evidence for six countries vis-à-vis Japan", *International Economic Journal*, 11, pp. 51-67.
[17] Ng, S. and P. Perron, 1995, "Unit root tests in ARMA models with data-dependent methods for the selection of the truncation lag," *Journal of the American Statistical Association*, 90, pp. 268-281.

[18] Ng, S. and P. Perron, 2001, "Lag length selection and the construction of unit root tests with good size and power," *Econometrica* 69, pp. 1519-1554.

[19] Perron, P., 1989, "The Great Crash, the oil price shock and the unit root hypothesis", *Econometrica* 57, pp. 1361-1401.

[20] Phillips, P.C.B. and S. Ouliaris, 1990, "Asymptotic properties of residual based tests for cointegration", *Econometrica*, 58, pp. 165-193.

[21] Phillips, P.C.B. and P. Perron, 1988, "Testing for a unit root in time series regression", *Biometrika*, 75, pp. 335-346.

[22] Sims, C.A., 1988, "Bayesian skepticism on unit root econometrics", *Journal of Dynamics and Control*, 12, pp. 463-474.

[23] Wu, Y. and H. Zhang, 1996, "Mean reversion in interest rates: New evidence from a panel of OECD countries", *Journal of Money, Credit and Banking*, 28, pp. 604-621.