MPRA

Munich Personal RePEc Archive

International Parities and Exchange Rate Determination

Zhao, Yan

31. March 2005

International Parities
and
Exchange Rate Determination

Yan Zhao[*]

Abstract

The model of equilibrium exchange rate combining purchasing power parity (PPP) and uncovered interest parity (UIP) is widely tested using the cointegration approach. Most of the recent studies, however, are deficient in the treatment of expectations and the power of tests.

This paper aims at resolving the two deficiencies by deriving and testing the yen/dollar exchange rate model. Perfect foresight is assumed to circumvent the expectation problem and a modification of cointegration variables is introduced to improve the power of tests.

With this new methodology, supportive evidence for the hypothesis of combining PPP and UIP is found in the short run: cointegration between the future exchange rate, price and interest rate differentials exists; the error correction model (ECM) is significant. The paper also suggests that it is the interest rate differential, rather than the price differential, that explains more of the movement of the nominal exchange rate in the short run. In the long run, however, the cointegration does not exist because the interest rate differential becomes exogenous.

[*] Graduate student in the Master course at the Otaru University of Commerce, Japan.
E-mail: g200304@edu-otaru.uc.ac.jp.

Acknowledgements

Contents

1. Introduction

Recently the question of exchange rate determination has been extensively researched. Knowing the level of equilibrium exchange rate is becoming an important issue in the field of international finance and macroeconomics, especially with the more integrated world economy. It is of vital importance not only for individuals and firms engaging in international trade and finance, but also for the monetary authorities conducting monetary policy. Moreover, the equilibrium exchange rate is an important macroeconomic policy variable for both developing and developed countries. As a result, almost all open macroeconomic theories involve the measurement of equilibrium exchange rate.

1.1. PPP as the First Exchange Rate Model

In the economic literature, purchasing power parity (PPP), which was put forth by Cassel (1921)[1], is the first theory to measure the equilibrium exchange rate level. Based on the law of one price (LOP), purchasing power parity states that the relative price determines the exchange rate movement.

According to the PPP hypothesis, the relative price is the main determinant of the exchange rate and if written in log forms, the exchange rate should be equal to the price differential. The common deviation of the exchange rate from the relative price and the more volatile exchange rate fluctuation in the post-floating period, however, prompted many economists to test the validity of purchasing

---

[1] Gustav Cassel 1921. *The World's Monetary Problems*. London: Constable.

power parity[2].   Recent tests of PPP have been typically based on the investigation of the time series property of the real exchange rate, which can be seen as the residuals from PPP.   These test results[3] indicate that PPP may not hold: the real exchange rates are not always stationary.   The failure of PPP in the short run is common.   Even in the long run, the validity of PPP is mixed.

1.2. Combining PPP with UIP (CHEER)

The failure of PPP caused many people to raise doubt on the PPP as the model of equilibrium exchange rate.   With the great expansion of world financial markets in the past twenty years, some economists put forward a model of equilibrium exchange rate that combines the purchasing power parity and uncovered interest parity (UIP).   UIP is derived on the assumption of foreign exchange market efficiency, i.e., there is no "excessive arbitrage opportunity". UIP states the relationship between the exchange rate and the interest rate differential, indicating that an increasing domestic to foreign interest rate differential will generate expected depreciation of the exchange rate.

The proponents of the model that combines PPP and UIP argue that PPP represents the equilibrium of goods market only.   They suggest that the price levels are not sufficient to capture all the factors causing fluctuations of the exchange rate without taking the world financial markets into account. According to their arguments, the exchange rate deviation from PPP is not

---

[2] Engel and Morley (2001) proposed a different view and they developed a model to show that the nominal exchange rate converges much more slowly than the prices.
[3] See Chapter 2 of this paper for more details of the literature survey of PPP.

surprising because of the existence of non-zero interest rate differentials.

The model that combines PPP and UIP reflects the idea that although PPP serves as an important measurement of the exchange rate movements, its predictive power can be enhanced by allowing for the effects of financial markets when calculating the equilibrium exchange rate level.   This methodology, therefore, is called as the *capital enhanced equilibrium exchange rate (CHEER)* approach by MacDonald (2000).   We adopt this terminology hereto in this paper.

The CHEER approach was first proposed by Juselius (1991) and then developed by Johansen and Juselius (1992).   Since then, the CHEER approach has become popular among economists in the field of exchange rate determination (See Chapter 2 for literature survey).

1.3. Two Problems of the CHEER Approach

Almost all papers on the CHEER approach try to find supporting evidence by searching for cointegration relationship among exchange rate, price and interest rate differentials.   Those papers, however, have two major problems.

The first problem is an inappropriate treatment of expectation in the cointegration model.   The cointegration relationship is often investigated between prices, interest rates and the *contemporaneous*, not the *expected future exchange rate*.   Since UIP states the relationship between interest rates and *expected future* exchange rate, their cointegration models are not consistent with the UIP hypothesis.   Therefore, their models do not combine PPP and UIP theories correctly.

The second problem is that their studies lack the power of rejecting the null hypothesis of no cointegration, casting doubt on the validity of CHEER hypothesis. Careful reading of those papers[4] reveals that the failure of cointegration often occurs in short data span while cointegration often becomes apparent in the longer data span. The contingent property on data span has the same similarity as PPP and UIP, which are also believed to be long-run phenomenon[5]. Is it possible that the failure of PPP or UIP causes the non-rejection of no cointegration[6]?

This paper shows that either a failure of PPP or UIP *does* result in non-rejection of no-cointegration. The reason is that the linear sum of error terms in PPP and UIP will not be stationary if *exactly one* of them fails to hold[7]. In this case, it is impossible to find evidence supporting the CHEER approach since the null of no cointegration cannot be rejected. If either PPP or UIP fails to hold, the variables in the cointegration analysis need to be modified to increase the possibility of finding cointegration. Thus, an appropriate step in the investigation of whether PPP and UIP hold is essential to improve the power of cointegration analysis. Since PPP and UIP are rather long-run than short-run phenomenon, we expect that it is necessary to distinguish the CHEER models according to the data span.

---

[4] See Section 2.3 of this paper.

[5] Most people believe PPP is a long-run phenomenon because price adjustment takes time. The conclusion about whether UIP is also a long-run phenomenon is not necessarily widely accepted, although some people find that UIP tends to hold better with longer data span.

[6] This sentence contains two "no" and looks awkward. It is technically accurate, however, since the null hypothesis of no cointegration is always tested in the CHEER approach. If the null hypothesis is rejected, we find supporting evidence of CHEER approach and vice versa.

[7] Either PPP or UIP fails, not both of them. The linear combination of the PPP and UIP errors can be cointegrated if both of them are nonstationary.

1.4. Solution of the Two Problems

   This paper aims at solving the above two problems in the CHEER approach. The first problem of expectation is circumvented in a straightforward way by introducing expectation in terms of perfect insight.   The future nominal exchange rate is thus taken as the substitute for the expected future exchange rate.   Expectation is necessary to represent UIP correctly and in some CHEER paper, an expectation is formed on the price differentials (See Stephens, 2004, for example.).   In reality, however, people do not always focus on goods markets because price level changes in all items are not easy to observe.   It is quite possible for them to expect future exchange rate changes from financial markets[8]. Moreover, the price level based expectation is prone to cause systematically expectation errors in the presence of "sticky domestic price" (Obstfeld and Rogoff, 1996).

   The second problem of the lack of power in tests is solved by distinguishing the short-run (post-floating period since 1973) model from that of long-run (past 130 years) model because PPP is tested to hold only in the latter.   PPP's failure in the short run prompts us to modify the CHEER model.   The modified short-run model is new in that it is a differenced model of that of the long run. The effect of the modification becomes apparent: we could not have rejected the null hypothesis of no cointegration if using the same model as the long run. Moreover, the coefficients of the error correction model (ECM) in the short run are

---

[8] The idea that people foresee future exchange rate from financial markets comes from the current account effect proposed by Obstfeld and Rogoff (1995).   "To the extent that interest rates react to variables that are affected by net foreign assests, the latter affects exchange rate too." (Cavallo and Ghironi, 2002)

significant, strongly supporting the validity of the CHEER approach.

The conclusion of the long-run analysis is a surprise: we can not reject the null of no cointegration although both PPP and UIP hold. Therefore, the CHEER approach fails. The econometric analysis reveals that this is because the relative interest becomes exogenous in the long run and it does not belong to the exchange rate determination system. The failure of the CHEER approach in the long run suggests that we should be careful about combining PPP and UIP when analyzing the historical data, in which the world financial markets are under-developed.

The remainder of this paper is structured as follows. Chapter 2 gives the literature survey of the PPP, UIP and CHEER approaches. Chapter 3 analyzes the short-run model. Chapter 4 analyzes the long-run model. Chapter 5 summarizes this paper.

2. Literature Survey

2.1 Review of PPP

2.1.1. What's PPP?

Purchasing Power Parity (PPP), which addresses the relationship between nominal exchange rate and prices, is one of the most important theoretical building blocks in international finance. The basic idea of PPP can be traced back as far as the writing of "Wealth of Nations" by Ricardo in the 19th century (Mark, 2001). The term PPP, however, was first introduced by Cassel (1921).

Based on the hypothesis of law of one price (LOP), PPP states that one good should be sold at the same price in domestic and foreign markets if denominated by the same currency. If we denote the domestic and foreign price levels by P_t and P_t^*, respectively. And if S_t represents the nominal exchange rate (foreign price of domestic currency), then PPP implies:

$$P_t = S_t P_t^* \tag{1}$$

More frequently, PPP is expressed in the *logarithm* forms. By changing to lower-case letters to denote the natural logs and isolating the exchange rate as the left-hand variable, we obtain:

$$s_t = p_t - p_t^* \tag{2}$$

Traditionally, equation (1) and (2) are referred as the *absolute* PPP and by taking first differences of (2), we get the *relative* PPP:

$$\Delta s_t = \Delta p_t - \Delta p_t^* \tag{3}$$

Equation (2) and (3) are simple in that only two variables, the nominal exchange rate and price levels, are involved. The nominal exchange rate is

definite.   The price levels, however, vary in a large degree and the selection of the price index is not unanimous.   Cassel[9] suggested the general price level, whether or not it contains prices of non-tradable goods.   Many people use the consumer price index (CPI) in empirical studies.   However, some people argue that the price index of tradable goods is more appropriate because of the Balasa-Samuelson Effect (1964).   For example, Hau (2000) pointed that the large exchange rate fluctuation can be attributed to the existence of non-tradable goods.   Kim and Ogaki (2004) showed that the half-lives for the real exchange rate based on producer price index are shorter than that based on CPI, the former of which is believed to contain more tradable goods.

   The CPI is the only price level available for the data spanning over one century.   And this is a practical reason for researchers to choose CPI when investigating long-run PPP hypothesis in addition to Cassel's original argument.   This paper also selects CPI to make the long-run (from 1870) analysis consistent with the short-run analysis.

2.1.2. Empirical tests of PPP

   With the development of time-series econometrics, recent tests for PPP have often been conducted by investigating whether it is possible to reject the null hypothesis of unit root in the real exchange rate.   The logarithm of real exchange rate, q_t, can be defined as:

---

[9]   The following Cassel's saying is excerpted from Frenkel's paper (1978):"Some people believe that Purchasing Power Parities should be calculated exclusively on price indices for such commodities as for the subject of trade between the two countries.   This is a misinterpretation of the theory…   The whole theory of purchasing power parity essentially refers to the internal value of the currencies concerned, and variations in this value can be measured only by general index figures representing as far as possible the whole mass of commodities marketed in the country."

$$q_t = s_t - p_t + p_t^*$$ (4)

Comparing equation (2) and (4) reveals that the real exchange rate q_t is equivalent to the deviation of PPP. Therefore, testing for PPP becomes the investigation of time series property of the real exchange rate: If the real exchange rate is tested to be *stationary*, we find evidence supporting PPP. Unit root test was first introduced into the test of PPP by Roll (1979) and later by Adler and Lehmann (1983). The unit root test approach has been popular in the past two decades.

Unit root tests on the real exchange rate q_t do not seem to be in favor of PPP: almost all of the short-run tests are unable to reject the null hypothesis of unit root, especially since the post-floating period exhibits large and persistent departure. Even in the long run, the evidence supporting PPP is mixed. These results led many economists to seek explanations for the failure of PPP.

In general, the failure of PPP is ascribed to the transportation costs, the existence of trade barriers and fixed exchange rates, and so on. Vast literature have been written on the "law of one price", which is the basic assumption of PPP[10]. For example, Isard (1977) provided striking evidence of the violation of "law of one price" from the U.S., Germany, Japan and Canada data. Engel and Rogers (1996) studied the U.S. and Canadian consumer price data and found that the law of one price generally failed[11]. Another explanation originates from Dornbush's influential "overshooting" model (1976)[12], which states that the monetary policy can enlarge the real exchange fluctuation.

---

[10] See Froot, Kim and Rogoff (1995) and Rogoff (1996) for survey of deviation from law of one price or "border effect".

[11] Engel showed that the prices of similar goods in two countries are more volatile than that of dissimilar goods within the same country.

[12] The overshooting model is later extended by Obstfeld and Rogoff (1995).

Some economists, however, began to take doubt on the unit root tests because the failure of PPP is still common. Frankel (1986) put forward a serious question about the unit root test, i.e., the lack of power problem. He pointed out that short data span used to examine the real exchange rate may not be long enough to reject the null hypothesis of unit root, even it is truly stationary.

Frankel's idea is later developed by some other economists. According to their argument, many economists have attempted to solve the data span problem[13]. Two ways have been widely used to circumvent this problem. One way is to use data of a longer span[14]. Frankel (1996), Edison (1987) and Lothian and Taylor (1996) have successfully rejected the null of random walk of the real exchange rate by using data longer than one century. The technique of increasing the data span, however, has been criticized because of the existence of various exchange regimes and structural breaks due to real shocks on so long a data span. For example, Papell and Prodan (2004) find that evidence of PPP can be increased from 9 to 14 out of 16 countries when allowing for structural breaks.

The other method of circumventing the data span problem is to use panel data, i.e., to increase the number of real exchange rates under the unit root test. The panel data technique was first proposed by Abuaf and Jorion (1990) and later developed by Levin and Lin (1993), Im, Pesaran and Shin (1997), and Maddala and Wu (1999). Some of these studies provided evidence supporting PPP. Panel data method need to be applied with some reserve, however, as this technique has two pitfalls. One is that the rejection of the null hypothesis of

---

[13] For example, see Lothian (1986), Froot and Rogoff (1995), Lothian and Taylor (1997).

[14] Only increasing the observation frequency without extending the data span can not improve the test power.

unit root cannot be logically interpreted that all of the real exchange rates under consideration are stationary. It only implies that at least one series of the real exchange rate is stationary. The other pitfall of the panel data test is that the small sample size distortion[15] problem will aggravate when more than one series of real exchange rates are examined.

Some people tested *relative* PPP in the belief that the trend in the real exchange can be removed by differencing. For example, Coakley et al. (2003) argues that the inflation differential will cause the nominal exchange rate to move proportionally even if important real shocks existed. This paper also tested *relative* PPP in the short run when *strict* PPP is tested to fail.

In recent years, there is a trend that some economists tried to test PPP in two new ways: non-linear method[16] and laboratory test (Fisher, 2001). Non-linear proponents argue that there are probably potential sources of nonlinearity in real exchange rates. For example, the imperfect mobility of international trade and the heterogeneous behavior in the foreign exchange market both create a band within which the exchange rate becomes extremely capricious. Fisher, one of the laboratory test pioneers, finds that both strict PPP and relative PPP holds well with the experimental data. He points that it is because the data in the laboratory is more "unambiguously accurate" and the environment is more "static" compared with the true data[17]. The non-linear adjustment method and laboratory test certainly leave room for further research.

---

[15] Schwert (1989) proposed the small size distortion problem in unit-root tests.
[16] See Michael et al. (1997), Sarantis (1999), Baum et al (2001), Taylor et al. (2001) and Bec et al. (2004).
[17] Fisher also tests interest parities (UIP and CIP) by focusing on the call market in his paper and finds supportive evidence. Besides the reasons mentioned in PPP, he further explains that call market is more efficient, which favors the hypothesis of UIP and CIP.

2.2 Review of UIP

2.2.1. What's UIP?

Uncovered Interest Parity (UIP) is derived from an equilibrium condition in international financial markets. Let I_t and I_t^* denote the domestic and foreign interest rates, respectively, and $E_t(s_{t+1})$ represents the expectation of nominal exchange rate at period (t+1), then UIP states:

$$1 + I_t = (1 + I_t^*)\frac{E_t(S_{t+1})}{S_t} \tag{5}$$

Equation (5) can be interpreted as that one unit of currency should have the same return whether invested in the domestic or the foreign markets at equilibrium. UIP equation is more often written in its log forms:

$$E_t(s_{t+1}) - s_t = i_t - i_t^* \tag{6}$$

where $\log E_t(S_{t+1}) = E_t(s_{t+1})$, $\log S_t = s_t$, $\log(1 + I_t) = i_t$ and $\log(1 + I_t^*) = i_t^*$.

Equation (6) gives the more apparent interpretation of UIP, i.e., the domestic and interest rate must be higher (lower) than the foreign interest rate by an amount equal to the expected depreciation (appreciation) of the domestic currency. If we use the forward exchange rate F_t instead of the expected future rate, we get Covered Interest Parity (CIP):

$$f_t - s_t = i_t - i_t^* \tag{7}$$

where $f_t = \log(F_t)$. The comparison of equation (6) and (7) suggests that test of UIP is equivalent to test whether $f_t = E_t(s_{t+1})$.[18]

---

[18] This test is first conducted by Hansen and Hodrick (1980). In their test, UIP is generally rejected except the dollar/Deutschemark case.

2.2.2. Empirical test of UIP

Although UIP implies the foreign exchange market efficiency, what Mark (2001) defines "there are no unexploited excess profit opportunities", empirical analysis reveals that violations of UIP are common and they present an important empirical puzzle in international finance.

Economists have presented various explanations for these apparent failures. Mark (2001) classified them into three reasons. The first is that the forward foreign exchange rate contains a risk premium. This argument says that UIP is derived under the hypothesis of risk neutral agents; in real foreign exchange markets, however, risk averters are more common. Risk averters demand a risk premium for the bearing of risky currencies. Engle Robert F. et al (1987) argues that the risk premium is time variant using ARCH-M model. Ogaki (1999) shows that the substitution between domestic and foreign bonds can be strong because of the potential risk. The literature on risk premium is vast (See the survey paper of Engel, 1996).

The second reason is the violation of the perfect information assumption. The real economy environment always changes but people will need time to know these changes and to adjust their behavior. During the learning and adjustment period, it is not a surprise that individuals make systematic prediction errors even though "they behave rationally". Ascribing the failure of UIP to the individual's incomplete understanding of the economy due to imperfect information is called the "peso-problem" approach, which was originally studied by Krasker (1980) and later developed by Lewis (1989). Krasker observed the interest rate differential between the Mexican peso and the U.S dollar and

showed that if the monetary authority would abandon the pegged exchange rate system, we could see the sequence of "systematic, serially correlated but rational forecast errors". Lewis proposes that the individuals may be unaware of the shift in economic fundamentals in the beginning, which can be associated with the economic or political environment. Individuals need time to learn this shift and during the adjustment period, rational forecast errors tend to be serially correlated and systematic.

The third explanation is that some market participants are actually "irrational" for the reason that they rely on the extraneous information (for example, rumor), not economic fundamentals, to predict the asset value. The individuals who do not behave irrationally are called "noise" traders, a name originally used by Black (1986). Black argued that the real world is too complicated for some (noise) traders to distinguish between the "pseudo and true" signals. Black suggested further that "noise" trader would generate excessive pseudo-signals, causing overdue optimism and pessimism. Therefore, the financial markets will be distorted by these "noise" traders and the exchange rate will deviate more from the valued based on the economic fundamentals. De Long et al. (1990) devised an overlapping generation model to study the pricing of foreign exchanges when "noise" traders generate excess trading volume and currency returns. Mark and Wu (1998) developed their model and used survey data to confirm that the "noise" traders caused spot and forward exchange dynamics.

In addition to the reasons aforementioned, some other economists argue that the failure of UIP lies in the data span. UIP is a long-run rather than a short-run phenomenon; therefore short span data is not appropriate. For

example, Alexius (2001) found supporting evidence for UIP using long-term government bond yields of 13 industrialized countries[19]. Meredith and Chinn (1998) researched on long-maturity bonds for G-7 countries and all the coefficients on interest differentials are of correct sign.

2.3 Cointegration Analysis of PPP and UIP

As stated beforehand, PPP concentrates on the goods market, while UIP emphasizes the financial markets. Some economists have tried to link them in a multivariate framework involving cointegration[20] and this approach is referred as a capital enhanced equilibrium exchange rate (CHEER). The approach captures the basic Casselian view of PPP that an exchange rate may be away from its PPP determined rate because of non-zero interest rate differentials[21]. In terms of balance of payments, the combination of PPP and UIP represents the interaction between current and capital account, respectively.

Johansen and Juselius (1992) are pioneers to combine PPP with UIP. They analyzed the long-run foreign transmission effects between the United Kingdom and the rest of the world and Juselius (1991) considered similar issues for Denmark and Germany; both focused on the long-run relations of PPP and UIP. Johansen and Juselius show that if PPP and UIP holds, then there will be two cointegration relationships among the following five variables: p_t, p_t^*, s_t, i_t and i_t^*. The two cointegration vectors are: (1,-1,-1,0,0) and (0,0,0,1,-1) to represent

---

[19] Alexius's paper deals with coupon payments in the long-term government bonds. Allowing coupon payments to affect the length of the investment period rather than the bond price, UIP holds better.
[20] We call two series cointegrated if they are integrated of the same order and the residual from their long-run relationship is stationary.
[21] See Officer (1976) for a detailed discussion of the Casselian view of PPP.

PPP and UIP hypothesis, respectively.

The cointegration approach has been conducted by some other economists later, most of which did not prove well. Messe and Rogoff (1988) could not find cointegration between the real exchange rate and real interest rate differential among the dollar, yen, and Deutsche mark. Campbell and Clarida (1987) find that the interest differential is not sufficient to explain the volatility of dollar exchange rate. Edison and Pauls (1993) allowed for current accounts in the cointegration approach to obtain negative results. Ledesma et al (1998) studied the Spanish case but found no cointegration among the exchange rate, price and interest differentials.

Some more recent studies yield promising results using CHEER approach. Cheng (1999) researched on yen/dollar case and found no causality between prices and exchange rates in the short run. However, causality is found running from relative prices to exchange rates along with interest rates in the long run. Juselius and MacDonald (2000) investigated dollar-mark relationship and found that a significant price adjustment towards equilibrium exchange rate level is compensated by long-term bond rates. Caporale et al (2001) investigated the German mark and Japanese yen to find evidence favorable to PPP and UIP with the aid of cointegration approach. Aysun and Ozmen (2002) studied the Turkish case and they found cointegration relationship among prices, interest rates and exchange rate with dollar. Their finding also suggests that PPP and UIP do not hold if tested separately.

In most of these papers, cointegration is searched between the *contemporaneous* exchange rate, price and interest rate differentials. Since UIP states the *expected future* rate, this cointegration does not represent PPP and

UIP hypothesis well. Taking aside this inappropriate treatment of expectation, conclusion about whether the cointegration relationship exists is mixed, causing some people to doubt the validity of the CHEER hypothesis. Is CHEER hypothesis misleading or the cointegration method lacks test power?

Careful review of these papers will suggest that all the papers succeeding in finding cointegration investigate the *long-run* phenomenon. Since PPP and UIP are believed to hold well in the long data span, we can expect that both of them hold in these papers, although they are not always explicitly tested. If both PPP and UIP do hold, there is no test power problem and cointegration relationship is easy to be detected, if there is any[22]. In the short data span, however, straightforward search of cointegration between exchange rate, price and interest rate differentials may fail due to the failure in either PPP or UIP. Cheng's paper (1999), for example, is unable to find cointegration in the short run but finds cointegration in the long run. Here it is important to note that when both PPP and UIP fail, it becomes possible to find evidence of supporting CHEER (Aysun and Ozmen, 2002, for example). The reason is that the sum of the two nonstationary residuals in PPP and UIP may be stationary because of the interaction of goods market and financial market.

Thus, we should modify CHEER approach to solve the lack of power in tests before concluding that the CHEER hypothesis is inappropriate. It is quite possible that the inappropriate treatment of expectation and the lack of test power explain the unsatisfactory results of the recent papers. This paper attempts to test this new hypothesis by solving the two deficiencies.

---

[22] It is also worth pointing out that cointegration may not necessarily exist when both PPP and UIP holds. See Chapter 4 for this paper.

3. Short-Run Analysis (Jan. 1973~Jun. 2004)

This section analyzes the floating period from January 1973 to June 2004. The data set contains the monthly nominal exchange rate, U.S and Japan's consumer price index and nominal interest rate[23]. In this paper, Japan is taken as the domestic country.

3.1. Pretests of PPP and UIP

3.1.1. Unit root process and Dickey-Fuller test

If PPP holds between U.S. and Japan, the shocks to yen's real exchange rate, q_t, should be temporary in that q_t will be mean-reversion. Specifically q_t is called stationary if it exhibits mean reversion and has a finite variance. A unit root process is not stationary. Consider the simple AR (1) process:

$$q_t = \rho q_{t-1} + \varepsilon_t \qquad (8)$$

where we assume that $-1 \leq \rho \leq 1$ and ε_t is white-noise with the variance of σ. By introducing the lag operator, L[24], we rewrite the above equation as:

$$(1 - \rho L)q_t = \varepsilon_t$$

When q_t is stationary, the autoregressive polynomial $(1 - \rho L)$ should be invertible, which requires that $\rho < 1$. Then it is equivalent to say that the root L in the autoregressive polynomial $(1 - \rho L)$ lies outside the unit circle.

If $\rho = 1$, then q_t becomes a random walk process, $\Delta q_t = \varepsilon_t$, and $q_t = \sum_{i=1}^{t} \varepsilon_t$ if we

---

[23] Considering a growing importance of international financial markets, I use the euro rates in this section.

[24] For any variable q_t, $L^k q_t = q_{t-k}$.

assume $q_1 = 0$. **Thus,**

$$Var(q_t) = \text{var}(\varepsilon_t + \varepsilon_{t-1} + \ldots + \varepsilon_1) = t\sigma^2$$

Therefore, q_t is no longer stationary because the variance depends on *t*. We should be careful about the nonstationary variables because there might be what Granger and Newbold (1974) called a s*purious* regression. A spurious regression has significant t-statistics and a high R^2, but the process is without any economic meaning. Therefore pretesting for nonstationarity the variables in a regression equation is of extremely importance. There are many kinds of unit-root tests and we first introduce the Dicker-Fuller (DF) test since it is the most straightforward and it is also the foundation of many other more complicated tests.

DF test begins by subtracting q_{t-1} from each side of equation (8) and then consider:

$$\Delta q_t = \gamma q_{t-1} + \varepsilon_t \tag{9}$$

where $\gamma = \rho - 1$. The parameter γ is of interest; if $\gamma = 0$, the q_t sequence contains a unit root. The test involves estimating equation (9) using OLS in order to obtain the estimated value of γ and the associated standard error. By comparing the resulting t-statistic with the appropriate value reported in the DF tables[25], we can determine whether to accept or reject the null hypothesis $\gamma = 0$.

3.1.2. Nonstationary process and PPP test

After introducing the basic property of unit root and its test method, we proceed to conduct some unit root tests on the yen/dollar real exchange rate.

---

[25] DF table contains three sub-tables for three different regression equations, respectively. Besides equation (6), the other two are: $\Delta q_t = \alpha_0 + \gamma q_{t-1} + \varepsilon_t$ and $\Delta q_t = \alpha_0 + \gamma q_{t-1} + \alpha_1 t + \varepsilon_t$.

Some tests used in the following sections will be more complicated and powerful than the DF test.

3.1.2-1 The DF test

We add a constant to the right side of equation (2) and regress the nominal exchange rate s_t on a constant and the price differential $(p_t - p_t^*)$,

$$s_t = \alpha + \beta(p_t - p_t^*) + \varepsilon_t \tag{10}$$

to obtain: $\alpha = 5.5767(348.3208)$ and $\beta = 1.6144(36.0596)$ with $t-value$ in the parenthesis.   PPP requires that:

$$\beta = 1 \tag{11}$$

The restriction is binding; however, the *F*-statistics value *188.3298* of equation (11) exceeds the 5 percent critical value of the *3.84* in the statistical table.   Let $q_t = s_t - p_t + p_t^*$ denotes the real exchange rate and we depict the graph of the nominal and real exchange rates and price differential as Figure 1.

Figure 1-A

Nominal and Real Exchange Rate in logs (Yen/Dollar)

Price Differential in logs (JP-U.S.)
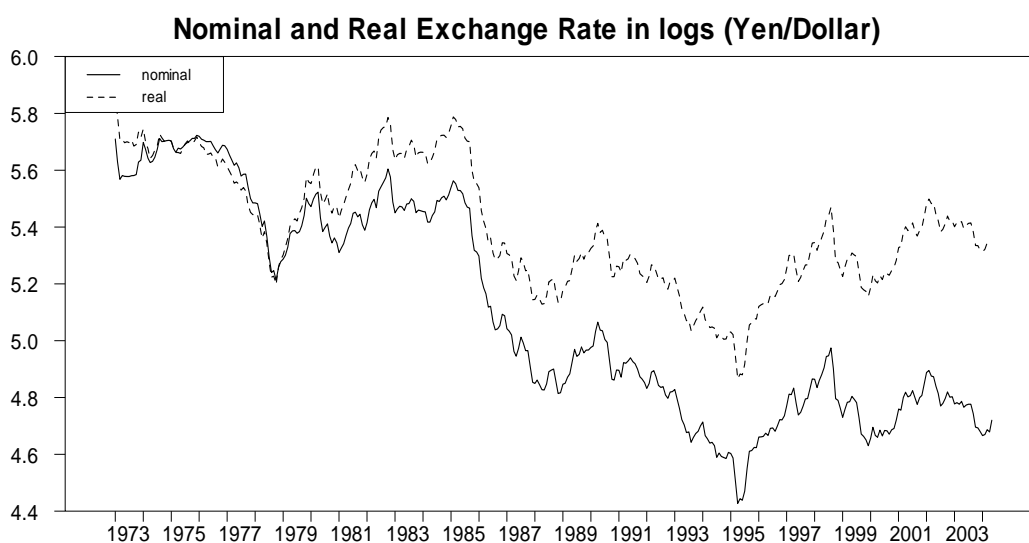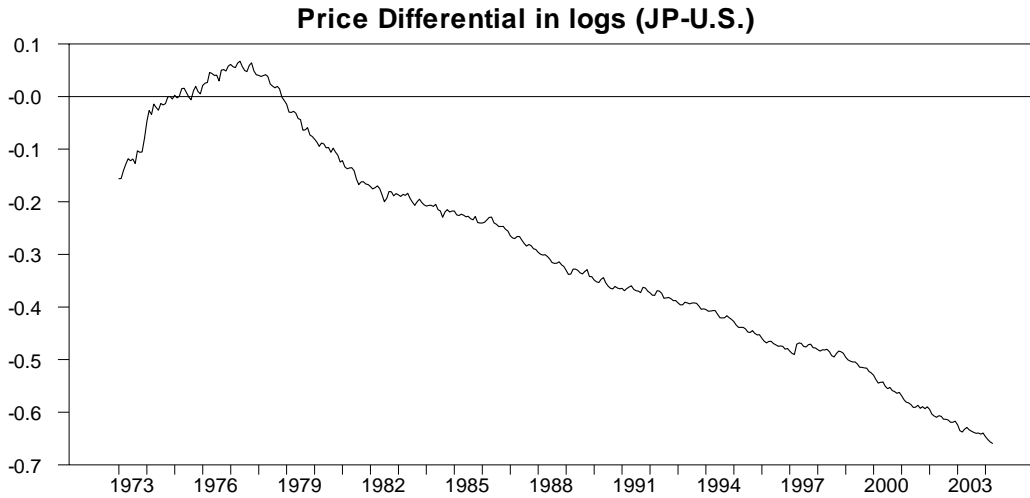
Source: DataStream and the author's calculation

We test for the unit root according to equation (9) $\Delta q_t = \gamma q_{t-1} + \varepsilon$ to obtain: $\gamma = $ -2.19143. Comparing the value of γ with the DF table implies that we can not reject the null of unit root process in q_t, because the absolute value of γ is smaller than that of the 10 percent critical value (-2.571), not to mention the 5 and 1 percent critical values $(-2.87$ and $-3.44)$.

3.1.2-2 The Augmented DF test

Not all time-series processes can be well represented by the first-order autoregressive process $\Delta q_t = \alpha_0 + \gamma q_{t-1} + \alpha_1 t + \varepsilon_t$. When we test unit roots in higher order equations such as the $pth - order$ autoregressive process, the DF test equation should be modified as:

$$\Delta q_t = \alpha_0 + \gamma q_{t-1} + \sum_{i=1}^{p} \beta_i q_{t-i} + \varepsilon_t \tag{12}$$

where $\gamma = -(1 - \sum_{i=1}^{p} \rho_i)$ and $\beta_i = \sum_{j=1}^{p} \rho_j$.

Equation (11) is called the augmented Dicker-Fuller (ADF) test and the coefficient of interest is γ; if $\gamma = 0$, the equation is entirely in first differences and so has a unit root. The ADF statistics table is the same as DF test.

Here we select $p = 4$ to test the sequence of Japanese real exchange rate q_t. The test result is: $\gamma = -0.013159$ with $t-value$ -1.9910. Since the $t-value$ is smaller than that of the corresponding 10 percent value (-2.57), the ADF test suggests that we can not reject the null hypothesis that $\gamma = 0$.

3.1.2-3 The Phillips-Perron Tests

The distribution theory supporting the Dicker-Fuller tests assumes that the errors are statistically independent and have a constant variance. The changes of the real exchange rate q_t are depicted as Figure 2, which strongly indicates that the sequence is serially correlated in that positive (negative) deviation persists for a rather period. Therefore, we should take some reservation about the power of the DF test.

Figure 2
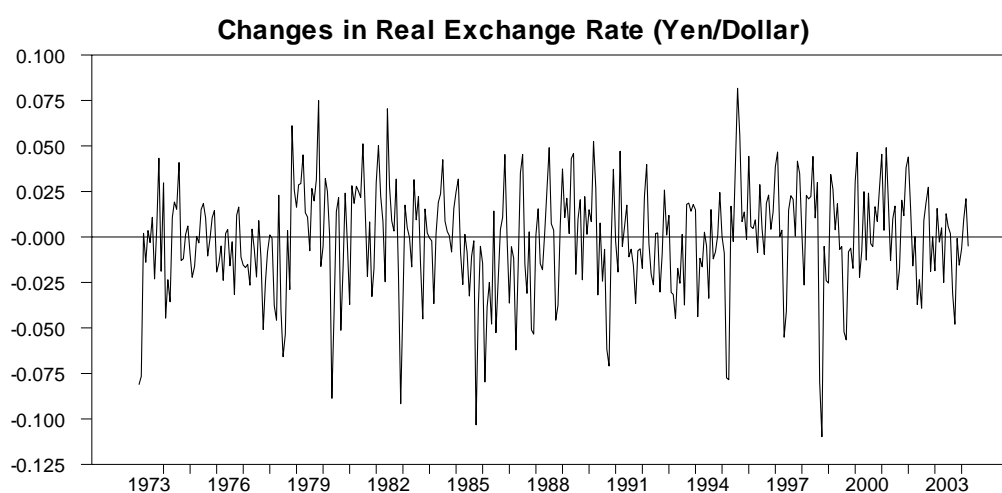
Source: DataStream and the author's calculation

Phillips and Perron (1988) developed a test procedure that allows for the distribution of errors. The Phillips-Perron test (PP test) statistics are modifications of the DF t-statistics and the critical values are precisely the same.

The conclusion based on the PP test is the same as DF test; the γ statistics value is tested to be -2.3588, absolute value lesser than the 10 percent critical value (-2.57).

From above we know that all kinds of unit root tests yield the same conclusion: we can not reject the null hypothesis of unit root in the process of real exchange rate q_t. Therefore, PPP does not seem to hold in the floating period.

Although PPP fails in this case, we can investigate further by testing relative PPP indicated by equation (3): $\Delta s_t = \Delta p_t - \Delta p_t^*$. Thus, unit root test on the "relative" real exchange rate Δq_t is necessary since it becomes the error term in equation (3).

$$\Delta q_t = \Delta s_t - \Delta p_t + \Delta p_t^* \tag{13}$$

The test results can be summarized as Table 1 with γ denoting the coefficient of the first difference of Δq_{t-1} in unit root tests.

Table 1: Summary of the Unit Root Tests for Δq_t

Test	DF	ADF	PP
t-statistics of γ	-13.8278	-8.5079	-13.7641

Compare the t-statistics or γ with the DF test table to know that all exceed the 1 percent critical value (-3.44). Therefore relative PPP seems to hold in the floating exchange rate period.

3.1.3. Stationary process and UIP test

Recall the UIP theory $E_t(s_{t+1}) - s_t = i_t - i_t^*$ and we know that to test UIP involves the estimation of future nominal exchange rate s_{t+1}. In this paper we assume the *perfect foresight*, i.e. there is no expectation error: $E_t(s_{t+1}) = s_{t+1}$. Under this assumption, UIP becomes: $s_{t+1} - s_t = i_t - i_t^*$.

Then we use the following regression to test UIP:

$$\varepsilon_t = \Delta s_{t+1} - \Delta i_t \tag{14}$$

where ε_t is the UIP error term, $\Delta s_{t+1} = s_{t+1} - s_t$ and $\Delta i_t = i_t - i_t^*$.[26] UIP holds if the error term ε_t is tested to be stationary. Like PPP test of equation (9), we are interested in whether $\gamma = 0$ in the equation,

$$\Delta \varepsilon_t = \alpha_0 + \gamma \varepsilon_{t-1} + \sum_{i=1}^{p} \beta_i \varepsilon_{t-i} + \tau_t \tag{15}$$

where τ_t is the error term.

The test result can be summarized as the Table 2. Since all the absolute values of t-statistics are greater than that of the 1 percent critical value (-3.453), we can reject the null of unit root. Therefore we conclude that the error term in UIP, ε_t is stationary and UIP holds in the floating period.

Table 2: Summary of the Unit Root Test for UIP

Test	DF	ADF	PP
t-statistic of γ	-7.4504	-4.6556	-7.3324

Figure 3, 4 and 5 depict the nominal and real interest differential and the

---

[26] Δs_{t+1} and Δi_t are both tested to be I(1) processes.

relative CPI changes between U.S and Japan in the floating period.

Figure 3

Nominal Interest DIfferential(Japan-U.S)
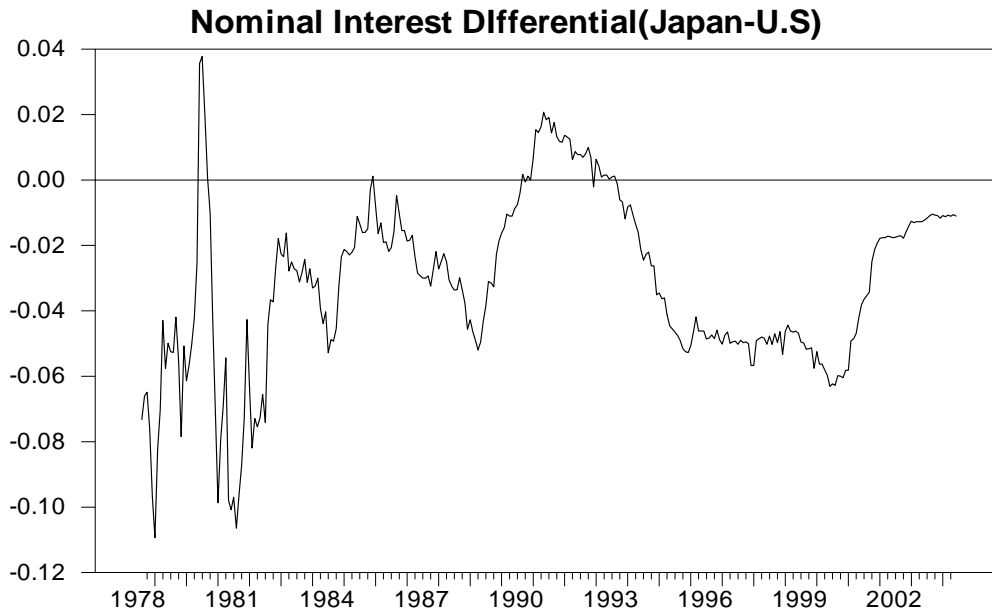
Source: DataStream

Figure 4
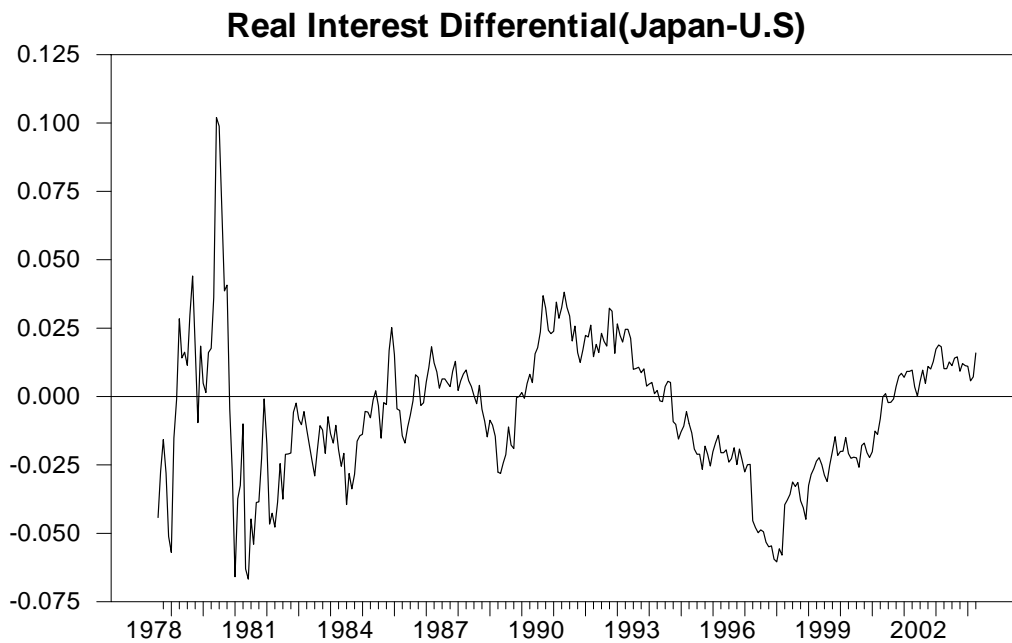
Real Interest Differential(Japan-U.S)

Source: DataStream and the author's calculation

Figure 5

CPI Index Change Differential(Japan-U.S)
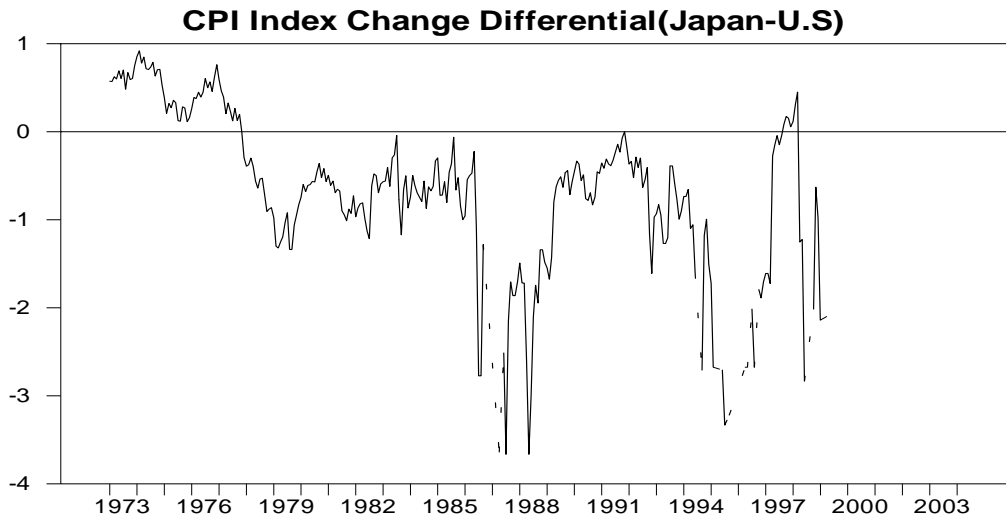
Source: DataStream and the author's calculation

3.2. The Model of Exchange Rate Determination

3.2.1. Is the relative price enough to determine the exchange rate?

The success of relative PPP may lead someone to believe that the price differential is enough to explain the movement of the nominal exchange rate. This section, however, argues that we should discard this optimistic idea.

Assume that only the price differential between Japan and U.S determines the Japanese nominal exchange rate, then we can write out this as the following p-th order bivariate vector autoregressive (VAR) system in its standard form:

$$s_t = a_{10} + \sum_{m=1}^{p} b_{1m} s_{t-m} + \sum_{m=1}^{p} c_{1m} (p - p^*)_{t-m} + \sum_{m=1}^{p} d_{1m} (i - i^*)_{t-m} + e_{1t} \tag{15-1}$$

$$(p - p^*)_t = a_{20} + \sum_{m=1}^{p} b_{2m} s_{t-m} + \sum_{m=1}^{p} c_{2m} (p - p^*)_{t-m} + \sum_{m=1}^{p} d_{2m} (i - i^*)_{t-m} + e_{2t} \tag{15-2}$$

where e_{1t}, e_{2t} are white-noise disturbances.

Equation (15) is called the restricted system in that all the coefficients of

interest differential, d_{1m} and d_{2m} are assumed to be zero. We will employ a block exogeneity test, which is useful for detecting whether to incorporate a variable into a VAR, to test whether the restriction is appropriate.

In empirical studies, we should determine the lag length p before performing the block exogeneity test. Here we use Akaike(1974) Information Criterion (AIC) and Schwartz (1978) Bayesian Criterion (SBC) criteria to aid in selecting the appropriate lag length:

$$AIC = T \log |\sum| + 2N \qquad \text{(16-1)}$$

$$SBC = T \log |\sum| + N \log(T) \qquad \text{(16-2)}$$

where $|\sum| =$ determinant of the variance/covariance matrix of the residuals

N = total number of parameters estimated in all equations.

Ideally, the AIC and SBC should be as small as possible (note that both can be negative). Under the assumption of both d_{1m} and d_{2m} to be zero, we calculate the values of the AIC and SBC based on different lags (Table 3). Apparently, Table 3 indicates that both AIC and SBC select the two lag model, i.e. $p = 2$.

Table 3: Summary of AIC and SBC Values in selecting lag *P*

Lags (p)	12	8	4	3	2	1
AIC	-6374.92	-6413.08	-6472.08	-6489.87	-6502.41	-6468.05
SBC	-6180.06	-6280.20	-6401.54	-6434.97	-6463.16	-6444.49

Let $\sum_r$ and $\sum_u$ be the variance/covariance matrices of the restricted and unrestricted systems, respectively, T represents the number of usable observations and let c denote the maximum number of regressors contained in the longest equation. Asymptotically, as recommended by Sims (1980), the test

statistics

$$(T - c)(\log | \sum{}_r | - \log | \sum{}_u |) \tag{17}$$

has a χ^2 distribution with degrees of freedom equal to the number of restrictions in the system.

If $p = 2$, the number of restrictions in equation (15) is 6 (lags 0,1,2 in each equation) and the statistics is calculated to be 50.6849, far exceeding the 1 percent critical value (16.81). The restriction is binding and therefore the interest differential is essential in the determination of the exchange rate.

3.2.2. The model of exchange rate determination

From the previous work, we know that both the relative PPP $\Delta s_t = \Delta p_t - \Delta p_t^*$ and UIP $s_{t+1} - s_t = i_t - i_t^*$ hold. Moreover, the interest rate differential should be included in the exchange rate determination besides the price differential. To derive the linkage between the PPP and UIP, we rewrite them as:

$$\Delta s_t = \Delta p_t - \Delta p_t^* + \eta_p \tag{18-1}$$

$$s_{t+1} - s_t = i_t - i_t^* + \eta_i \tag{18-2}$$

where η_p and η_i are the error terms. By differencing equation (18-2) we get:

$$\Delta s_{t+1} - \Delta s_t = \Delta (i_t - i_t^*) + \Delta \eta_i \tag{18-3}$$

and by substituting (18-1) into the (18-3) we obtain:

$$\Delta s_{t+1} = \Delta(p_t - p_t^*) + \Delta(i_t - i_t^*) + \eta \tag{19}$$

where $\eta = \eta_p + \Delta \eta_i$.

Equation (19) is a model of nominal exchange rate determination; it can be interpreted that the increases in either price or the interest rate differentials will cause the future nominal exchange rate to depreciate. For example, if a country is suffering higher inflation or sharp interest rate increasing, its exchange rate

will depreciate according to equation (19).   We can proceed to set a VAR system

as:

$$\Delta s_t = a_{10} + \sum_{m=0}^{p} b_{1m} \Delta s_{t-m} + \sum_{m=0}^{p} c_{1m} \Delta(p - p^*)_{t-m} + \sum_{m=0}^{p} d_{1m} \Delta(i - i^*)_{t-m} + e_{1t} \qquad \text{(20-1)}$$

$$\Delta(p - p^*)_t = a_{20} + \sum_{m=0}^{p} b_{2m} \Delta s_{t-m} + \sum_{m=0}^{p} c_{2m} \Delta(p - p^*)_{t-m} + \sum_{m=0}^{p} d_{2m} \Delta(i - i^*)_{t-m} + e_{2t} \qquad \text{(20-2)}$$

$$\Delta(i - i^*)_t = a_{30} + \sum_{m=0}^{p} b_{3m} \Delta s_{t-m} + \sum_{m=0}^{p} c_{3m} \Delta(p - p^*)_{t-m} + \sum_{m=0}^{p} d_{3m} \Delta(i - i^*)_{t-m} + e_{3t} \qquad \text{(20-3)}$$

System (20) is not in the *standard* or *reduced* form in that it contains contemporaneous variables in two sides of the same equation.   It is called *structural* VAR since the model structure is based on the economic theory.

3.3. Econometric Analysis

3.3.1. Cointegration analysis

The same ordered variables are said to be cointegrated if there exist a linear combination that yields a stationary process.   If the nominal exchange rate determination model described by equation (19) is appropriate, we can say that the three variables concerned are cointegrated: Δs_{t+1}, $\Delta(p_t - p_t^*)$ and $\Delta(i_t - i_t^*)$. We will use Engle-Granger methodology to test for the cointegration between them.

The first step is to pretest the orders of integration.   Cointegration necessitates that the variables be integrated of the same order.   Various tests including Dicker-Fuller (DF), augmented Dicker-Fuller (ADF) and Phillips-Perron (PP) tests are used on the three variables in the model to reach

the conclusion that Δs_{t+1}, $\Delta(p_t - p_t^*)$ and $\Delta(i_t - i_t^*)$ are all $I(0)$ processes[27].

The second step is to get the long run equilibrium relationship by regressing:

$$\Delta s_{t+1} = \alpha + \beta_p(\Delta p_t - \Delta p_t^*) + \beta_i(\Delta i_t - \Delta i_t^*) + \varepsilon_t \qquad (21)$$

where ε_t is the error term.   The regression result is reported in Table 4.

Table 4: Estimation of the Exchange Rate Determination Model

coefficient	value	Std Error	t − statistics	significance
α	-0.0034	0.0018	-1.87	0.0622
β_p	-0.7465	0.3372	-2.2136	0.0276
β_i	0.1402	0.1950	0.7190	0.4727

Let $\varepsilon_t^{/}$ denote the estimated error term from equation (21) to distinguish itself from the real error terms ε_t.   The residual of $\varepsilon_t^{/}$ should be checked for unit roots to find whether it is stationary or not.   If it is stationary, we can conclude that cointegration exists among Δs_{t+1}, $\Delta(p_t - p_t^*)$ and $\Delta(i_t - i_t^*)$ and vice versa. The following two equations are estimated:

$$\Delta \varepsilon_t^{/} = \alpha_1 \varepsilon_{t-1}^{/} + e_t \qquad (22\text{-}1)$$

$$\Delta \varepsilon_t^{/} = \alpha_1 \varepsilon_{t-1}^{/} + \sum \alpha_{i+1} \Delta \varepsilon_{t-i}^{/} + e_t \qquad (22\text{-}2)$$

where e_t are white noise.

It should be noted that we should not use the DF table because the residuals $\varepsilon_t^{/}$ in equation (22) are not the actual error terms.   Only when we know the actual errors in each period can we use the DF table.   Engle and Granger (1987) perform the set of Monte Carlo experiments to construct the confidence intervals

---

[27] s_{t+1}, $(p_t - p_t^*)$ and $(i_t - i_t^*)$ are all tested to be I (1) processes; their first difference are all stationary.

for α_1 in equation (22).   Under the null hypothesis $\alpha_1 = 0$, the critical values for the t-statistics depend on whether or not the lags are included (Table 5[28]).

Table 5: Critical Values for the Null of No Cointegration

significance	*0.01*	*0.05*	*0.10*
No Lags	-4.07	-3.37	-3.03
Lags	-3.73	-3.17	-2.91

The estimated t-statistics of α_1 in (22.1) and (22.2) are -12.47557 and -7.9515, respectively, both exceeding the critical values for the null hypothesis of no cointegration at 1 percent level.   Therefore, we can reject the null hypothesis of no cointegration and conclude that CHEER approach is supported in the short run.

3.3.2. The effect of the modification and the increased test power

It is worthy noting that the supportive evidence of CHEER approach is found according to equation (19), the first-order differenced model.   In most of the recent CHEER papers, however, cointegration is directly searched between s_{t+1}, $(p_t - p_t^*)$ and $(i_t - i_t^*)$.   Here we will show that this modification is necessary because we can not find cointegration if using the same method as the recent papers.

Now we proceed to use Johansen methodology, the more powerful cointegration test, to investigate the cointetgration relationship between s_{t+1}, $(p_t - p_t^*)$ and $(i_t - i_t^*)$.   Johansen methodology circumvents the small sample size

---

[28] Table 5 is excerpted from Enders (1995).

distortion problem and it can detect the multiple cointegration vectors. Further, the unnecessary step-by-step approach in Johansen methodology avoids any potential enlarged error from the previous step. The Johansen test results are summarized in Table 6[29].

Table 6-1: Summary of the Johansen test between s_t, $(p_t - p_t^*)$ and $(i_t - i_t^*)$

Eigenv	L-max	Trace	H0: r	p-r	L-max95	Trace95
0.0679	20.83	39.77	0	3	21.07	31.52
0.0483	14.66	18.95	1	2	14.90	17.95
0.0144	4.29	4.29	2	1	8.18	8.18

Table 6-2: Summary of the Johansen test between s_{t+1}, $(p_t - p_t^*)$ and $(i_t - i_t^*)$

Eigenv	L-max	Trace	H0: r	p-r	L-max95	Trace95
0.0617	18.85	40.37	0	3	21.07	31.52
0.0562	17.11	21.52	1	2	14.90	17.95
0.0148	4.40	4.40	2	1	8.18	8.18

Table 6-3: Summary of the Johansen test between Δs_{t+1}, $\Delta(p_t - p_t^*)$ and $\Delta(i_t - i_t^*)$

Eigenv	L-max	Trace	H0: r	p-r	L-max95	Trace95
0.1487	47.51	87.52	0	3	21.07	31.52
0.0817	25.14	40.01	1	2	14.90	17.95
0.0492	14.88	14.88	2	1	8.18	8.18

Table 6-1 is the result of Johansen methodology based on the cointegration

---

[29] Source of the *L-Max* and *L-Trace* statistics: Enders (1996)

analysis between the *contemporaneous* exchange rate, price and interest rate differentials, which is the method adopted by most of the other researchers. Table 6-2 gives the cointegration analysis between the *expected future* exchange rate, price and interest rate differentials while Table 6-3 is the result of the modified model, i.e., the differenced model of equation (19). Comparing the results in the three sub-tables, we conclude that the effect of this modification is significant. Only Table 6-3, i.e., the sub-table with the modified model can yield the cointegration relationship[30].

3.3.3. The error correction model (ECM)

According to Granger representation theorem, cointegration and error correction are equivalent representations, i.e. cointegration implies error correction and vice versa. The next stage involves the error correction model for the VAR system (20), which should have the form of:

$$\Delta(\Delta s_{t+1}) = \alpha_1 + \beta_1 \Phi + \Pi_1 + e_{1t} \tag{23-1}$$

$$\Delta\Delta(p - p^*)_t = \alpha_2 + \beta_2 \Phi + \Pi_2 + e_{2t} \tag{23-2}$$

$$\Delta\Delta(i - i^*)_t = \alpha_3 + \beta_3 \Phi + \Pi_3 + e_{3t} \tag{23-3}$$

where $\Phi = \Delta s_t - \alpha - \beta_p (\Delta p_{t-1} - \Delta p_{t-1}^*) - \beta_i (\Delta i_{t-1} - \Delta i_{t-1}^*)$ [31],

$\Pi_n = \sum \beta_{sn} \Delta(\Delta s_{t+1}) + \sum \beta_{pn} \Delta(\Delta p_t - \Delta p_t^*) + \sum \beta_{in} \Delta(\Delta i_t - \Delta i_t^*), n = 1, 2, 3$

e_{1t}, e_{2t} and e_{3t} = white-noise disturbances which may be correlated with each other and α, β are parameters.

Φ represents the real error ε_{t-1} in equation (21). Since $\varepsilon_{t-1}^{/}$ is the

---

[30] In Table 6-1 and Table 6-2, *L-Max* and *L-Trace* contradicts each other in that only the latter rejects cointegration. We should pin down the number of cointegration vectors and therefore we conclude that there is no cointegration.

[31] β_p and β_i are the cointegrationg vectors given by equation (21).

estimation of deviation from long-run equilibrium in period $(t-1)$, as proposed by Engle and Granger, it is possible to use the saved residuals $\{\varepsilon'_{t-1}\}$ obtained from the regression of equation (21) as an instrument for the expression Φ. Based on this substitution, the error-correction model (ECM) is estimated to be:

$$\Delta(\Delta s_{t+1}) = -0.00013 - 0.76179\varepsilon'_{t-1} + \Pi_1 + e_{1t} \qquad (24\text{-}1)$$

$$(-7.8129)\ (0.00000)$$

$$\Delta\Delta(p - p^*)_t = -0.012055\varepsilon'_{t-1} + \Pi_2 + e_{2t} \qquad (24\text{-}2)$$

$$(-0.65688)\ (0.5118)$$

$$\Delta\Delta(i - i^*)_t = 0.0001 + 0.033\varepsilon'_{t-1} + \Pi_3 + e_{3t} \qquad (24\text{-}3)$$

$$(1.02725)\ (0.3052)$$

The value in the parenthesis under each equation shows t-value and the significance level. In equation (24.1), the error-correction term is of highly significance level. This suggests that the future change of exchange rate is strongly determined by the long-run equilibrium. Further, the sign of the error-correction terms ε_{t-1} in equation (24.2) is not consistent with the theory, making (24.2) looks more like error-amplifying rather than error-correction. The significance level, however, is very low. This indicates that the differenced price level is rather rigid and does not respond to the deviation from the long-run equilibrium level much.

3.3.4. Causality test and innovation accounting

In VAR analysis, we say that q_{1t} does not Granger-cause q_{2t} if the lagged values of q_{1t} do not appear in the equation for q_{2t}, that is, the current and lagged q_{1t} do not help to predict the future value of q_{2t}. The null hypothesis that q_{1t} does not Granger-cause q_{2t} can be tested by doing a joint F-test: regress q_{2t} on both the lagged q_{1t} and the lagged q_{2t} and see the significance of the coefficient of lagged q_{1t}.

The following part of this section investigates the Granger causality relationship among the three variables in the exchange rate determination model: Δs_{t+1}, $\Delta(p_t - p_t^*)$ and $\Delta(i_t - i_t^*)$ while performing the innovation accounting.

Based on the VAR system (20), we first conduct the Granger causality test. The F-test and the corresponding significance level are reported in Table 7.

Table 7: Summary of Granger-Causality Tests

variable	Δs_{t+1}		$\Delta(p_t - p_t^*)$		$\Delta(i_t - i_t^*)$	
Δs_{t+1}	21.57	*0.000*	0.024	*0.976*	0.722	*0.487*
$\Delta(p_t - p_t^*)$	4.121	*0.017*	7.184	*0.001*	5.234	*0.006*
$\Delta(i_t - i_t^*)$	1.741	*0.177*	0.361	*0.697*	2.622	*0.074*

Table 7 shows that Δs_{t+1} Granger-causes only itself; $\Delta(i_t - i_t^*)$ also roughly Granger-causes only itself, while $\Delta(p_t - p_t^*)$ Granger-causes all the three variables.

To further identify the different roles $\Delta(p_t - p_t^*)$ and $\Delta(i_t - i_t^*)$ play in the model of exchange rate determination, we can decompose the forecast error variance. The forecast error variance decomposition tells us the proportion of the movements in a sequence due to its own shocks versus shocks to the other variables.

We use the variance matrix in the VAR system (20) to obtain 1-step ahead through 24-step ahead forecast errors. Appendix 4 shows the first five impulses, together with the variance decomposition. To measure all responses in terms of standard deviations, we depict the following impulse response functions.
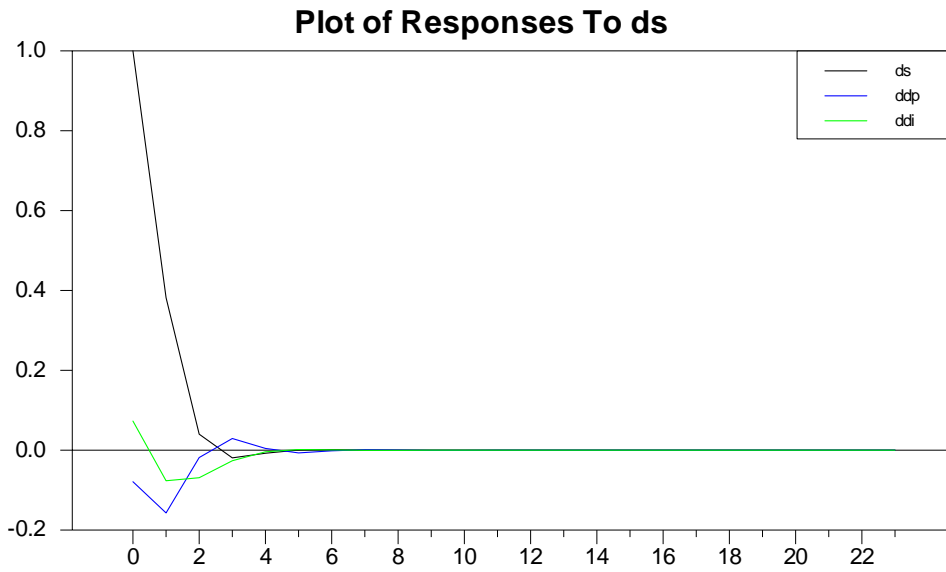
Figure 6-1

Plot of Responses To ds

Figure 6-2

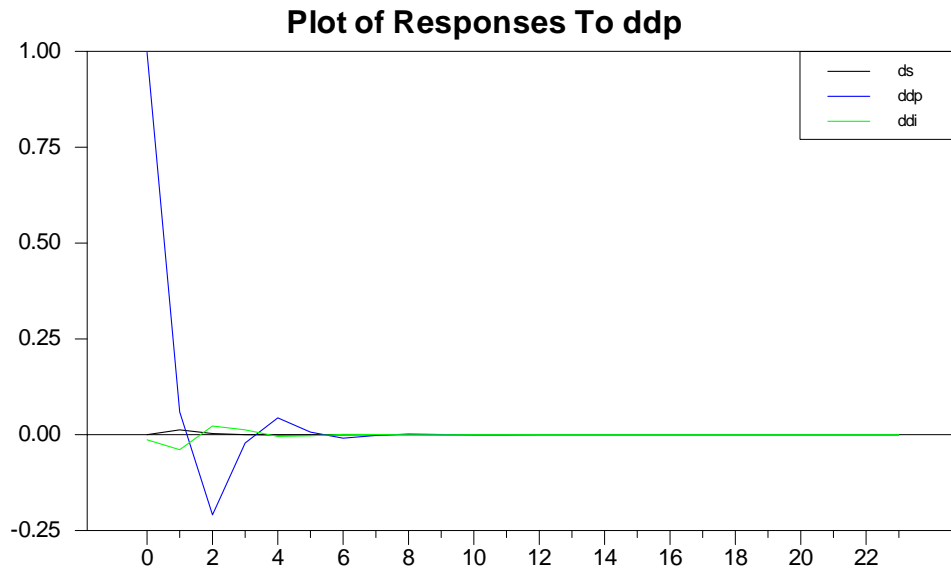## Plot of Responses To ddp

Figure 6-3

Plot of Responses To ddi
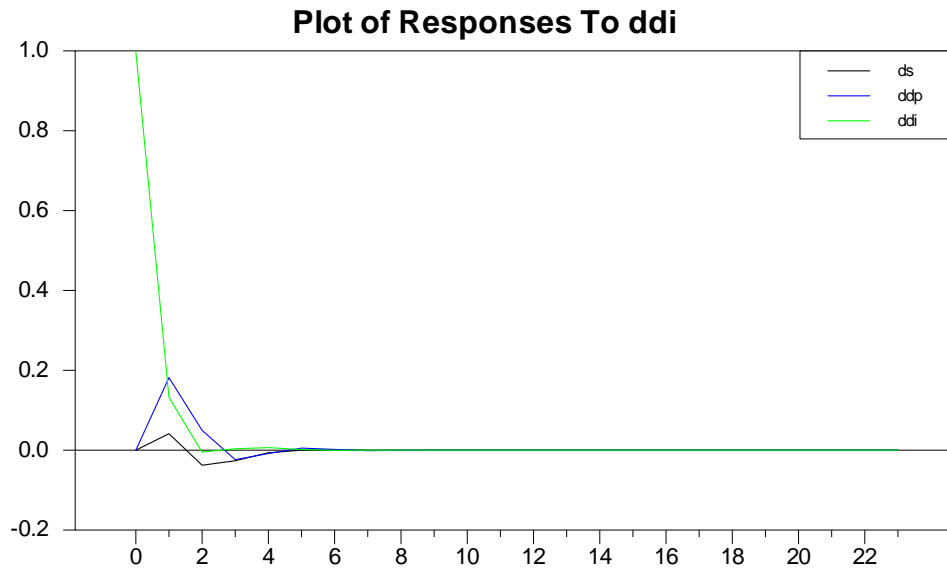
Note: $ds = \Delta s_{t+1}, ddp = \Delta(p_t - p_t^*)$ and $ddi = \Delta(i_t - i_t^*)$.

Source: DataStream and the author's calculation

From the Granger causality test and innovation accounting analysis, we can see that the price differential itself can not explain all the movements of the future nominal exchange rate. $\Delta(p_t - p_t^*)$ explains only **0.011** percent of the movement of Δs_{t+1} while $\Delta(i_t - i_t^*)$ explains **0.34 percent in the 5-lag (five month) ahead horizon.** The differenced interest rate differential serves as a "channel" in the sense that it does not Granger cause Δs_{t+1} directly but it explains more of the movement of the exchange rate. Some of the effects of $\Delta(p_t - p_t^*)$ on Δs_{t+1} are conveyed by this "channel": $\Delta(p_t - p_t^*)$ affects $\Delta(i_t - i_t^*)$ and then $\Delta(i_t - i_t^*)$ affects the nominal exchange rate movement.

The exchange rate determination model is derived from the economic theories and the differenced variables make it a little difficult to grasp the real effects since differencing tends to smooth the various shocks. Moving away the

difference in equation (19) to set up a VAR system containing s_{t+1}, $(p_t - p_t^*)$ and $(i_t - i_t^*)$ and plotting the impulse response function will give a more apparent impression, as shown in Figure 7. The movement of s_{t+1} resembles $(i_t - i_t^*)$ to a great extent (Figure 7-3).

Figure 7-1
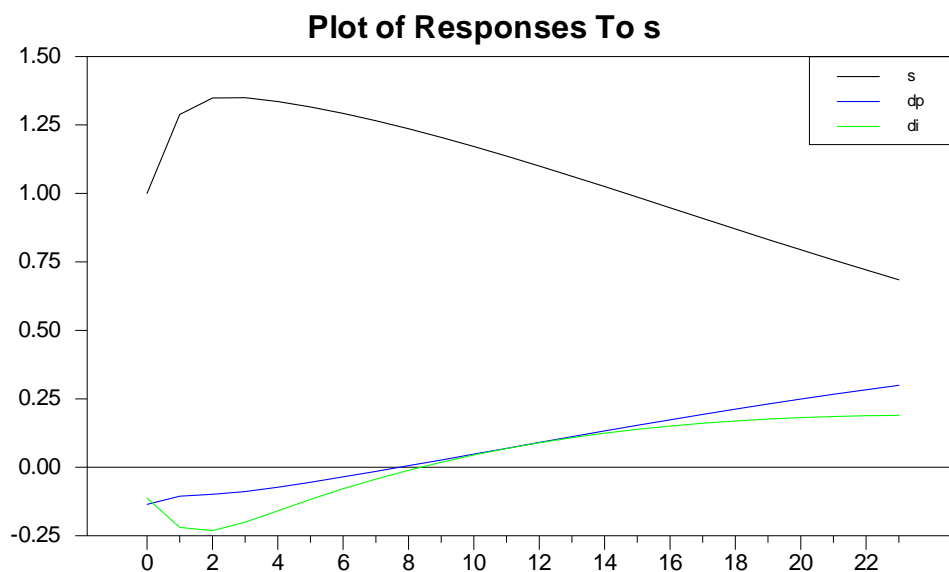
Figure 7-2

Figure 7-3

Plot of Responses To di
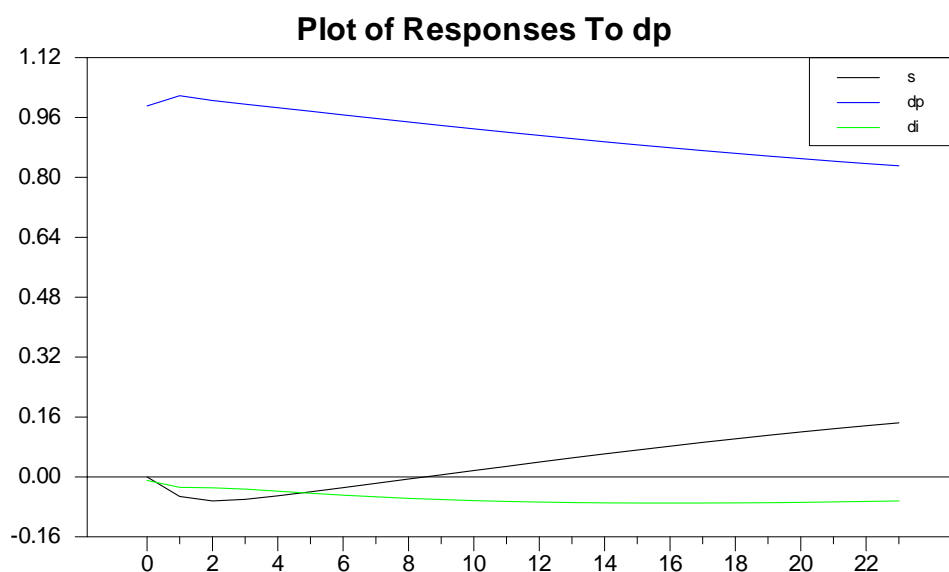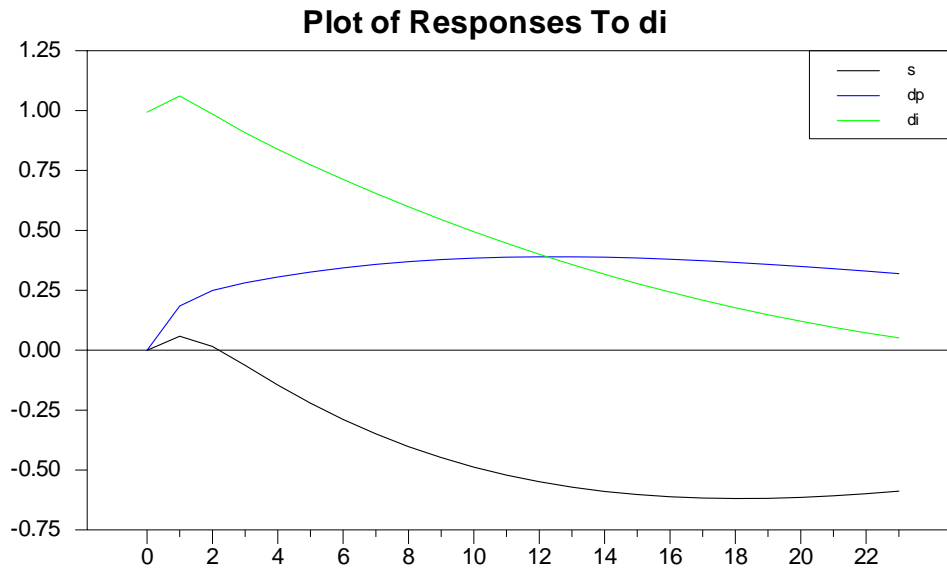
Note: $s = s_{t+1}, dp = (p_t - p_t^*)$ **and** $di = (i_t - i_t^*)$

Source: DataStream and the author's calculation

Moreover, considering the interest rate differential is small in value and differencing it may cause it to appear white noise[32], its effect tends to be underestimated in model (19). Granger causality test between s_{t+1}, $(p_t - p_t^*)$ and $(i_t - i_t^*)$ yields a different result, as is shown in Table 8.

Table 8: Summary of Granger Causality Tests

variable	s_{t+1}		$(p_t - p_t^*)$		$(i_t - i_t^*)$	
s_{t+1}	6599	*0.000*	2.286	*0.103*	7.41	*0.001*
$(p_t - p_t^*)$	3.45	*0.033*	61750	*0.000*	5.86	*0.003*
$(i_t - i_t^*)$	4.832	*0.009*	1.423	*0.243*	1229	*0.000*

---

[32] The mean of $\Delta(i_t - i_t^*)$ is 0.000201.

The value in italic forms shows the significance level. As indicated from the Table 8, in the 5 percent significance level, the price differential $(p_t - p_t^*)$ Granger-cause both s_{t+1} and interest rate differential $(i_t - i_t^*)$; $(i_t - i_t^*)$ Granger-causes s_{t+1} and it explains 9.715 percent of the 12-lag ahead forecast error of s_{t+1}, leaving $(p_t - p_t^*)$ only account for 0.772 percent in the same period. Therefore, the interest differential seems more essential in the determination of exchange rate movement in the short run.

4. Long-Run Analysis (Year 1870~2003)

4.1. The CHEER Model of Exchange Rate Determination

Analysis of Chapter 3 is based on the monthly data in the post floating period spanning 31 years (from 1973 to 2004); this chapter employs longer data span, which is annual data spanning from year 1870 to 2003. This data set contains the exchange rate, the CPI index and the long-term interest rates for U.S and Japan[33].

4.1.1. Unit root tests

The unit root tests for PPP and UIP are performed in the first step to determine whether they hold. Here we also assume perfect foresight, i.e., $E_t(s_{t+1}) = s_{t+1}$ in UIP hypothesis. As shown in equation (9) and (15), the unit root tests can be conducted by testing the null hypothesis that $\gamma = 0$. The test statistics are abbreviated as Table 9.

Table 9: Unit root tests

Test	DF	PP	ADF[34]
γ in PPP equation	-3.3485	-3.2633	-1.61463
γ in UIP equation	-8.1145	-8.3654	-3.19689

The 5 percent critical value for the null that $\gamma = 0$ is -2.883 and all the

---

[33] Long-term interest rates are U.S 10 year government bond yield and Japanese 7 year government bond yield. The maturities are different because no other long-run rate is available.

[34] The lags in ADF equations are 8.

absolute value of the statistics reported in Table 9 exceed this except the ADF statistics for PPP, which is -1.61463. As Campbell and Perron (1991) pointed out, nonrejection of the unit root hypothesis may be due to the existence of structural breaks. From year 1870 to 2003, at least two structural breaks occurred. As Figure 8 shows, one is year 1945, in which the yen depreciated more than 200 percent (from 4.29 to 15). The other notable break is year 1970, in which the yen began to appreciate sharply due to the oil shock[35].

Considering the existence of two structural breaks, we should detrend the real exchange rate before performing the unit root tests. First, we regress:

$$q_t = a_0 + a_1 t + \mu_1 D_{L1970} + \mu_2 D_{L1985} + \hat{q}_t$$

where D_{L1970} and D_{L1985} are level dummies representing structural breaks in year 1970 and 1985, respectively;

μ_1 and μ_2 are coefficients of D_{L1970} and D_{L1985}, respectively;

t represents time and a_0, a_1 are parameteres.

Then, we perform the unit root test on the detrended real exchange rate, $\hat{q}_t$ to regress:

$$\Delta \hat{q}_t = \alpha_0 + \gamma \hat{q}_{t-1} + \sum_{i=1}^{8} \beta_i q_{t-i}$$

The estimated t-statistics for $\gamma = 0$ is -3.1515, exceeding the 5 percent critical value of -2.883. Therefore, we conclude that the null hypothesis of unit root can be rejected and both PPP and UIP hold in the long run. The graph of nominal and real exchange rate, changes in real exchange rate and interest rate

---

[35] Year 1985 may be considered as another break for the advent of the Plaza Agreement. It is not necessary to deal with it here, however, since we have taken year 1970 as a break and we can view year 1985 as a point in the appreciation trend of yen.

differential are depicted in Figure 8,9,10 and 11.

Figure 8
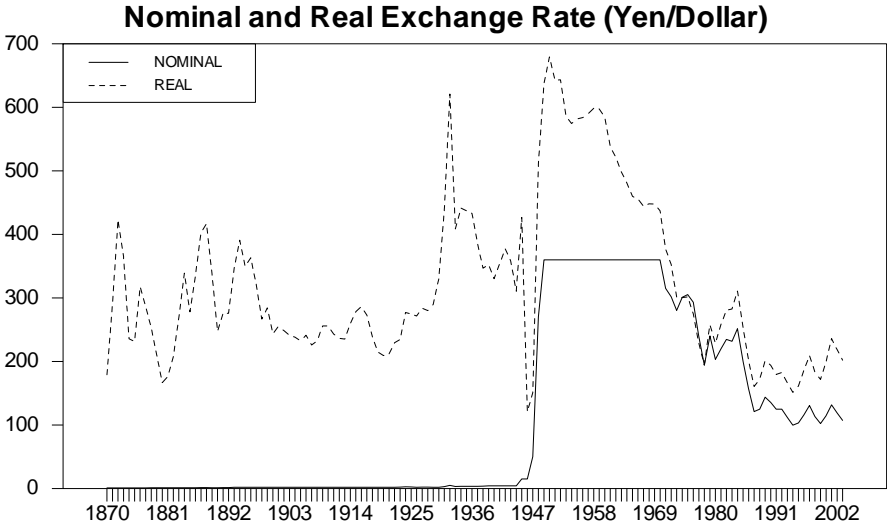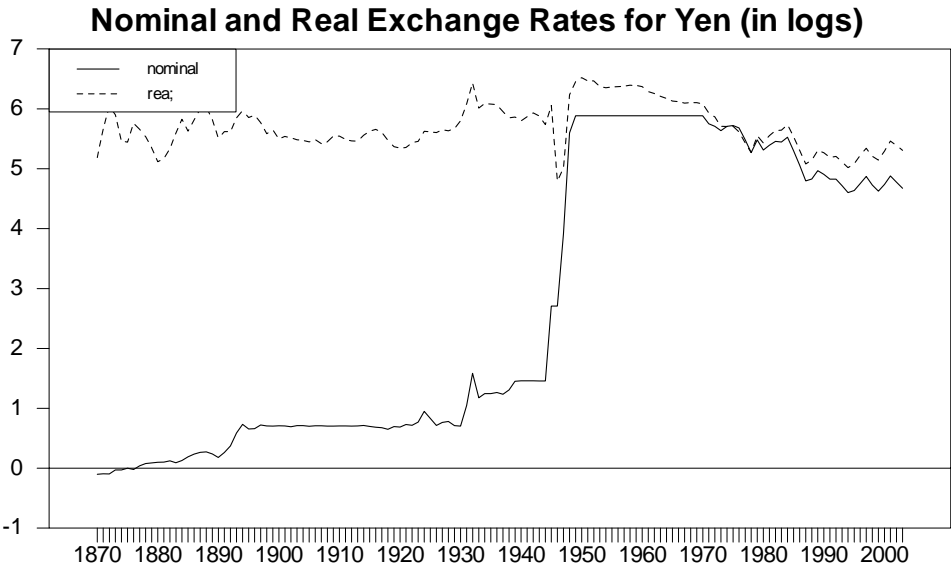
Nominal and Real Exchange Rate (Yen/Dollar)

Source: DataStream and the author's calculation

Figure 9

Nominal and Real Exchange Rates for Yen (in logs)

Source: DataStream and the author's calculation

Figure 10

Changes In Real Exchange Rate of Yen

Source: DataStream and the author's calculation

Figure 11

Nominal Interest DIfferential(Japan-U.S) in log value
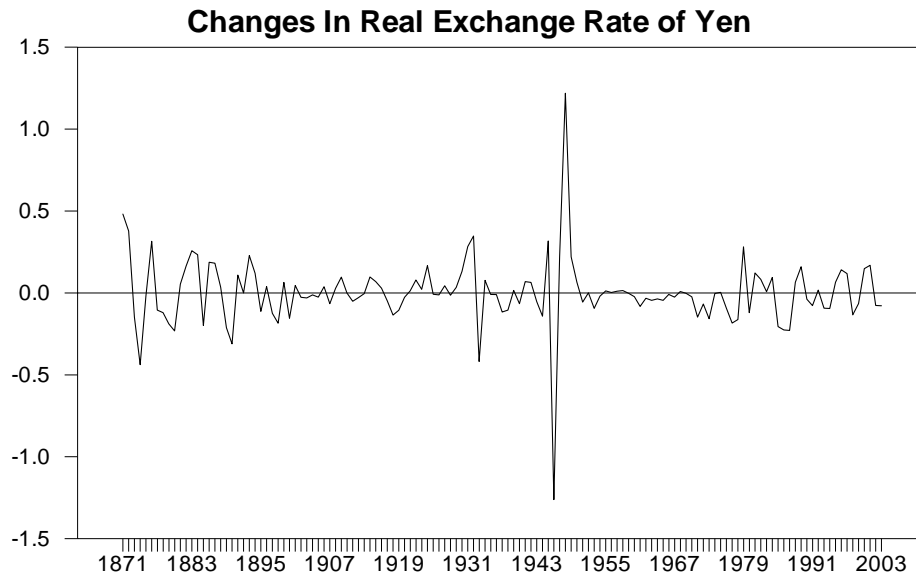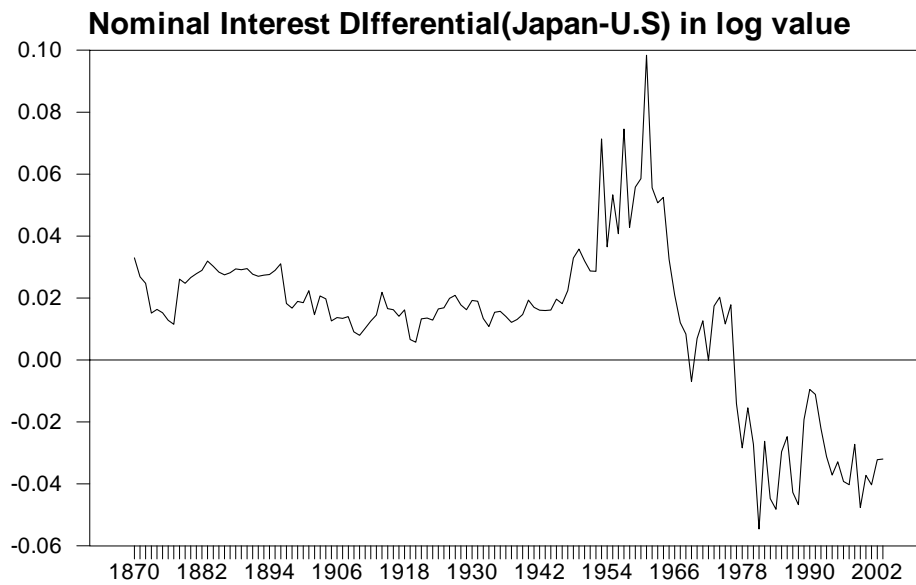
Source: DataStream

4.1.2. The nominal exchange rate determination model

The PPP and UIP can be written in the following equations:

$$s_t = p_t - p_t^* + \eta_p \tag{25}$$

$$s_{t+1} - s_t = i_t - i_t^* + \eta_i \tag{26}$$

where η_p and η_i are residuals.

Regress equation (25) and (26) and we obtain:

$$s_t = 5.748 + 1.017(p_t - p_t^*)$$

(107.0) (71.7)

$$s_{t+1} - s_t = 0.026 + 0.7645(i_t - i_t^*)$$

(1.08) (1.005)

The t-statistics are shown in the parenthesis and the null hypothesis of coefficients of $(p_t - p_t^*)$ and $(i_t - i_t^*)$ equal to unity cannot be rejected[36].

By substituting (25) into equation (26), we can obtain the following equation:

$$s_{t+1} = (p_t - p_t^*) + (i_t - i_t^*) + \varepsilon_t \tag{27}$$

where $\varepsilon_t = \eta_p + \eta_i$.

Equation (27) is the determination of nominal exchange rate in the long run. It can be interpreted that the future nominal exchange rate is determined by the current price and interest rate differentials. In this equation, three variables are concerned, s_{t+1}, $(p_t - p_t^*)$ and $(i_t - i_t^*)$. According to equation (27), we can set up a VAR model as:

$$s_t = a_{10} + \sum_{m=0}^{p} b_{1m} s_{t-m} + \sum_{m=0}^{p} c_{1m} (p - p^*)_{t-m} + \sum_{m=0}^{p} d_{1m} (i - i^*)_{t-m} + e_{1t} \tag{28-1}$$

---

[36] The F-statistics of the null that the coefficient equal to 1 is tested to be 1.3576 and 0.09183 in equation (25) and (26) respectively, which is less than the 1 percent critical value 6.63.

$$(p - p^*)_t = a_{20} + \sum_{m=0}^{p} b_{2m} s_{t-m} + \sum_{m=0}^{p} c_{2m} (p - p^*)_{t-m} + \sum_{m=0}^{p} d_{2m} (i - i^*)_{t-m} + e_{2t} \qquad \textbf{(28-2)}$$

$$(i - i^*)_t = a_{30} + \sum_{m=0}^{p} b_{3m} s_{t-m} + \sum_{m=0}^{p} c_{3m} (p - p^*)_{t-m} + \sum_{m=0}^{p} d_{3m} (i - i^*)_{t-m} + e_{3t} \qquad \textbf{(28-3)}$$

where *a, b, c,* and *d* are parameters, and $e_{it} (i = 1, 2, 3)$ are error-terms.

The lag length in system **(28)** is determined using AIC and SBC criteria, whose value is the smallest when 3 lags are used. Therefore, we set $p = 3$.

4.2. Engle-Granger Cointegration Test and ECM

We also adopt Engle-Granger approach to test the cointegration relationship among the three variables concerned in equation **(27)**: s_{t+1}, $(p_t - p_t^*)$ and $(i_t - i_t^*)$. Pretests of the order of their integration indicate that they are all I(1) processes.

The next step entails regressing on the following equation to get the long-run equilibrium relationship.

$$s_{t+1} = \alpha + \beta_p (p_t - p_t^*) + \beta_i (i_t - i_t^*) + \varepsilon_t^{/} \qquad \textbf{(29)}$$

where $\varepsilon_t^{/}$ is the estimated error. The result of the regression is reported in Table 10.

Table 10: Regression Results in the Long Run

coefficient	value	Std Error	t − statistics	significance
α	5.7580	0.0433	133.001	0.000
β_p	1.0519	0.012	87.8757	0.000
β_i	10.8902	1.0525	10.3468	0.000

Just the same as equation **(22)** in Section 3.3.1, we regress the following equation to know the t-statistics of α_1.

$$\Delta\varepsilon_t' = \alpha_1\varepsilon_{t-1}' + e_t \tag{30-1}$$

$$\Delta\varepsilon_t' = \alpha_1\varepsilon_{t-1}' + \sum \alpha_{i+1}\Delta\varepsilon_{t-i}' + e_t \tag{30-2}$$

where e_t are white noise.

The estimated t-statistics of α_1 in (30.1) and (30.2) are *-5.6731* and *–3.4221*, respectively, and both exceeding the critical values for the null of no cointegration at 5 percent level (*-3.17* with lags and *–3.37* without lags respectively).   Moreover, by changing the regression order, i.e., changing the left side variable in equation (29) do not lead to different results.   The t-values of the estimated errors both exceed the critical value in the Engle-Granger no cointegration table.   Therefore, we can reject the null of no cointegration.

After the cointegration test, we then estimate the ECM, which should have the form as the following if we substitute ε_{t-1}' with the real error term ε_{t-1},

$$\Delta s_{t+1} = \alpha_1 + \beta_1\varepsilon_{t-1}' + \Pi_1 + e_{1t} \tag{31-1}$$

$$\Delta(p - p^*)_t = \alpha_2 + \beta_2\varepsilon_{t-1}' + \Pi_2 + e_{2t} \tag{31-2}$$

$$\Delta(i - i^*)_t = \alpha_3 + \beta_3\varepsilon_{t-1}' + \Pi_3 + e_{3t} \tag{31-3}$$

where

$\Pi_1 = \beta_{p1}\Delta(p_t - p_t^*) + \beta_{i1}\Delta(i_t - i_t^*)$, $\Pi_2 = \beta_{s2}\Delta s_{t+1} + \beta_{i2}\Delta(i_t - i_t^*)$, $\Pi_3 = \beta_{s3}\Delta s_{t+1} + \beta_{p3}\Delta(p_t - p_t^*)$,

e_{1t} , e_{2t} and $e_{3t} =$ white-noise disturbances which may be correlated with each other; and α , β are parameters.

System (31) is estimated to be:

$$\Delta s_{t+1} = 0.007 + (-0.0260)\varepsilon_{t-1}' + \Pi_1 + e_{1t} \tag{32-1}$$
$$(0.385) \quad (-0.296)$$

$$\Delta(p - p^*)_t = 0.021 + 0.165\varepsilon_{t-1}' + \Pi_2 + e_{2t} \tag{32-2}$$
$$(1.818) \quad (3.130)$$

$$\Delta(i - i^*)_t = -0.0004 + 0.0113\varepsilon_{t-1}' + \Pi_3 + e_{3t} \tag{32-3}$$
$$(-0.359) \quad (2.432)$$

`   The value in the parenthesis below each estimated coefficient is the corresponding t-value.   Careful examination of system (32) would reveal that if $\varepsilon_{t-1}^{/}$ is positive, i.e., if s_{t+1} is larger than the long-run equilibrium level, then the ECM will make it to decrease while $(p-p^*)_t$ and $(i-i^*)_t$ to increase, making it possible to restoring to the equilibrium.   Therefore, different from the short run ECM, the long-run ECM is stable.

Although the ECM is stable in the long run, the coefficient of $\varepsilon_{t-1}^{/}$ in equation (32-1) is not significant, implying the exchange rate does not respond to the long-run deviation.   What makes this coefficient be insignificant?   We expect to answer this question by performing the Granger causality tests to reveal the intrinsic relationship between the variables in system (28).

4.3. Granger Causality and Johansen Methodology

Granger causality test between s_{t+1}, $(p_t - p_t^*)$, $(i_t - i_t^*)$ are helpful to further reveal the roles each variable plays in the long-run nominal exchange rate determination.   The joint F-statistics and the significance levels of system (28) are reported in Table 11.

Table 11: Granger Causality Tests for the Long Run

variable	s_{t+1}		$(p_t - p_t^*)$		$(i_t - i_t^*)$	
s_{t+1}	89.91	*0.000*	12.87	*0.000*	0.042	*0.989*
$(p_t - p_t^*)$	16.91	*0.000*	154.13	*0.000*	1.482	*0.223*
$(i_t - i_t^*)$	2.300	*0.081*	1.696	*0.172*	59.404	*0.000*

Table 11 indicates that at 5 percent significance level, s_{t+1} and $(p_t - p_t^*)$ both Granger-cause themselves and each other; $(i_t - i_t^*)$ Granger-causes only itself and is not Granger-caused by any of the other two. These results imply that the interest rate differential $(i_t - i_t^*)$ is not an endogenous variable in the system of exchange rate determination.

The exogenous property of interest rate differential raises a serious question of system (28), i.e., is it appropriate to include $(i_t - i_t^*)$ in the VAR system? Because the likely ratio test can determine whether a variable should be included, we perform the likely ratio test of $(i_t - i_t^*)$. Begin with PPP equation (25), suppose that $\sum_{p=o}^{4} (i_{t-p} - i_{t-p}^*)$ should not be included, the likely ratio statistics[37] is 8.831921 with significance level 0.54812587, less than the 5 percent critical value of 18.30704. Therefore, the null hypothesis of exclusion of $(i_t - i_t^*)$ can not be rejected.

The Granger Causality tests and likely ratio tests both questions the hypothesis of CHEER in the long run. Because CHEER approach is often tested with the cointegration method, we proceed to use Johansen methodology, the more powerful cointegration test, to reinvestigate the cointetgration relationship. As stated in Section 3.3.2., Johansen methodology circumvents the small sample size distortion problem and it can detect the multiple cointegration vectors. Further, the unnecessary step-by-step approach in Johansen methodology avoids any potential enlarged error from the previous step.

According to the CHEER model of equation (27), we perform the Johansen

---

[37] The test equation is similar with equation (15). Here the number of restrictions is 10 (lag 0,1,2,3,4 in each equation) and the unrestricted model contains 12 coefficients.

test to detect the cointegration between the exchange rate, price and interest rate differentials.   The Johansen test results are summarized in Table 12.

Table 12: Johansen Cointegration Test

Eigenv	L-max	Trace	H0: r	p-r	L-max95	Trace95
0.1286	17.89	27.22	0	3	21.07	31.52
0.0510	6.80	9.33	1	2	14.90	17.95
0.0192	2.52	2.52	2	1	8.18	8.18

Table 12 indicates that the null hypothesis of no cointegration vector among s_{t+1}, $(p - p^*)_t$ and $(i - i^*)_t$ can not be rejected either by the *L-max* or *Trace* statistics.   Therefore, the CHEER approach fails in the long run and the exchange rate determination model is only represented by PPP.

The fact of CHEER hypothesis in the long run is a surprise because we have found cointegration in the short run and many economic hypotheses tends to hold better in the long run.   We can explain the puzzle from the history of financial markets.   Financial markets did not develop well until the past twenty years and its role in the exchange rate determination is not apparent if we view it in a very long data span.   If we test CHEER hypothesis using the recent data, the interest rate differential tends to become more significant because of its notable size.   In short, the 130 years is too long and the effect of financial market in exchange rate determination in recent years is "diluted".

The forecast error decomposition also suggests that the price differential $(p_t - p_t^*)$ is the dominant factor in the determination of s_{t+1}.   In the 5-lag ahead forecast horizon, $(p_t - p_t^*)$ explains about 10 percent of the error of s_{t+1}, while

$(i_t - i_t^*)$ explains about 0.1 percent (See Appendix 5).

Figure 12 depict the impulse response functions. The responses of s_{t+1} resembles that of $(i - i^*)_t$ in the short run; however, it resembles $(p - p^*)$ in the long run and the price differential affects it more in magnitude.

Figure 12-1

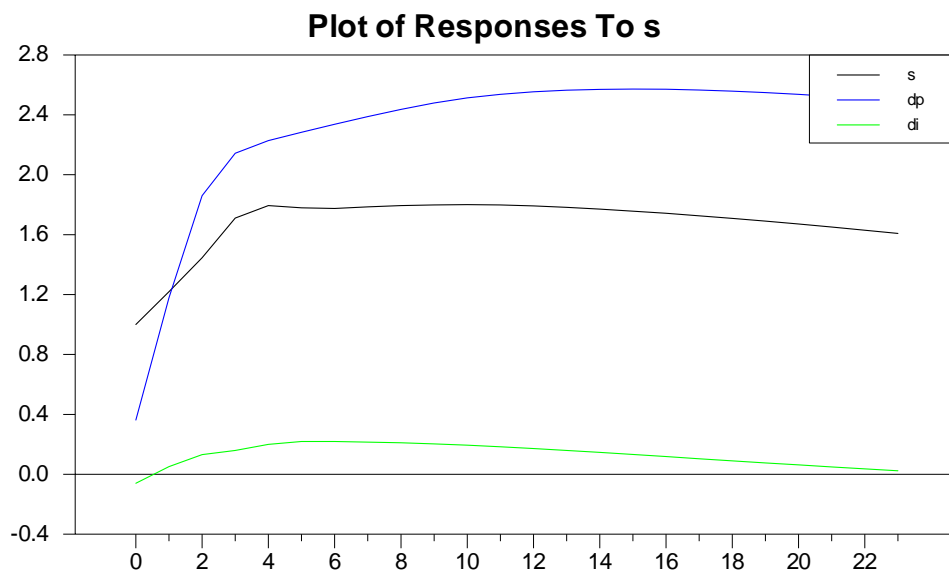
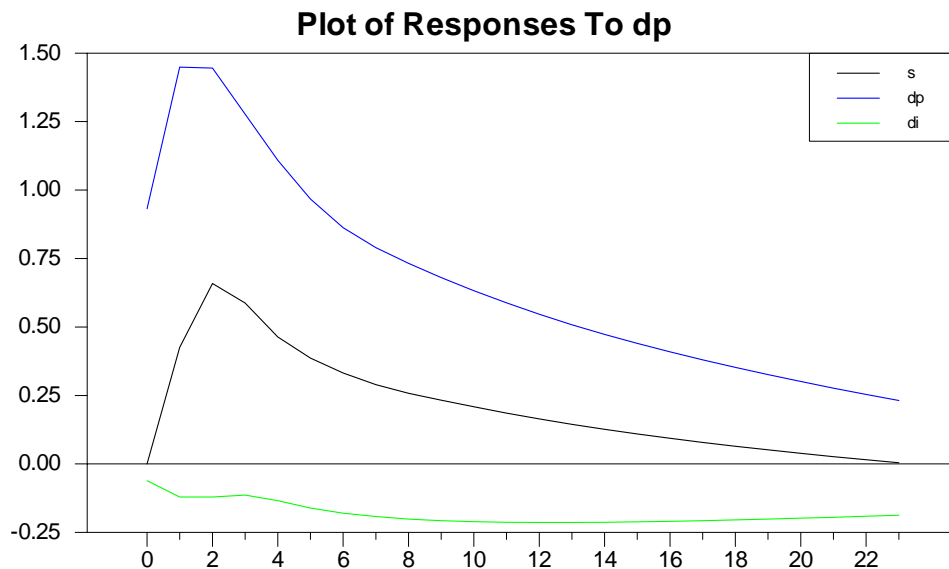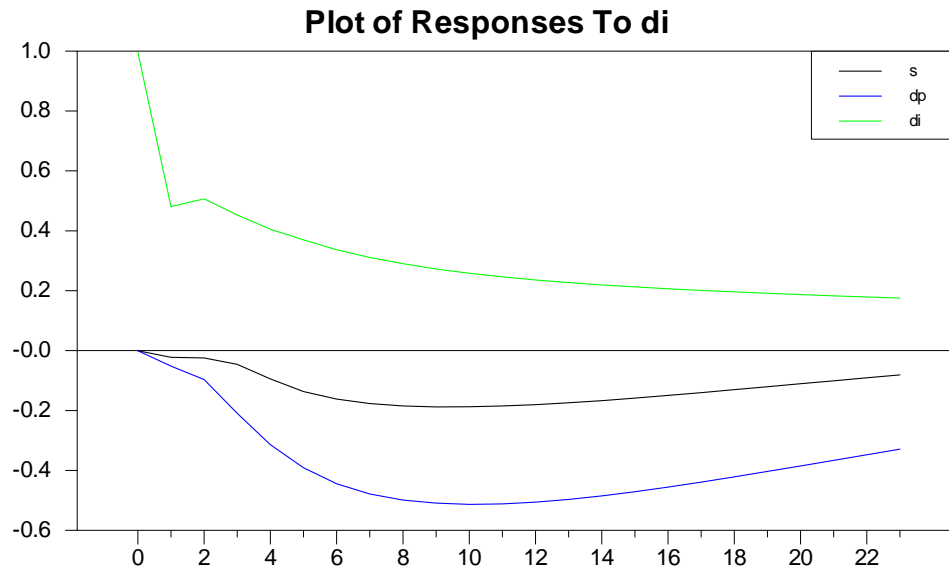**Plot of Responses To s**

Figure 12-2

Plot of Responses To dp

Figure 12-3

Plot of Responses To di

Note: $s = s_{t+1}, dp = (p_t - p_t^*)$ **and** $di = (i_t - i_t^*)$.

Source: DataStream and the author's calculation

5. Conclusion

The major conclusion of this paper is that the validity of the exchange rate model combing PPP and UIP strongly depends on the data span. Either failure of PPP or UIP will lead to no cointegration between the future exchange rate, price and interest rate differentials without appropriate modification of the cointegration variables. The cointegration relationship does not necessarily exist, however, even when both PPP and UIP hold. Further, in the VAR model of exchange rate determination, the roles of price and interest rate differentials play in the exchange rate determination are remarkably different between the short run and the long run.

In the short-run analysis during the floating period with monthly data, PPP fails and UIP holds. The variables in the CHEER approach are differenced to improve the test power of the cointegration analysis. With this modification, cointegration is found between the future exchange rate, price and interest rate differentials. The likely ratio test indicates that the interest rate differential is an endogenous variable and it explains more of the movement of the future exchange rate. The Granger causality tests indicates that although both the price and interest differentials Granger-cause the future nominal exchange rate, some effects of the price differential is transmitted by the interest differential, making the latter explain more forecast variance of the exchange rate. The coefficients in ECM are significant; however, because of the price rigidity, the ECM is not stable in the short run.

In the long-run analysis using yearly data of longer than one century, both UIP and PPP hold. The interest rate differential becomes an exogenous variable

in that it only Granger-cause itself and is not Granger-caused by any of the other two. Further, the likely ratio tests suggest that the interest rate differential does not belong to the exchange rate determination model, and therefore it should not be included in the VAR system. The price differential is the dominant factor in the future exchange rate determination and it is also strongly affected by the exchange rate. The interest rate differential only explains a negligible portion of the forecast error of the exchange rate. Although the Engle-Granger methodology yields cointegration between the future exchange rate, price and interest rate differentials, the ECM is of poor quality because the coefficient of exchange rate is not significant, implying the exchange rate does not respond to the long-run deviation. Therefore, the Johansen methodology is employed to reinvestigate the relationship since it is more powerful. The Johansen test rejects cointegration. Therefore, the CHEER hypothesis does not work well in the long run.

The validity of CHEER in the short run and its failure in the long run looks like a puzzle because many economic theories tend to hold better in the long run. This puzzle can be explained by the development of financial markets. The world financial markets have not been fully developed until recently. As Reinhart and Rogoff (2002) pointed out, the freely floating regime for yen did not begin until the end of 1977, before which the yen was either managed to float or pegged.

Because the basic idea of the CHEER approach is to jointly consider the goods and financial markets to determine the exchange rate, it is not a surprise that cointegration is easy to find if we use the recent data, in which the financial markets have developed and become large in comparison to the goods market.

For the same reason, supportive evidence of CHEER becomes difficult to find when we use the long-run historical data, in which the world financial markets are not fully developed. In this paper, the short-run and long-run data span the past 30 years and the 130 years, respectively. The effect of financial markets in the long run is "diluted" by the 100 years (from 1870 to 1970s) of the long-run data. Therefore, we expect that the CHEER approach will be supported with new future data.

The findings of this paper have important policy implications for monetary authorities. In the short run, it is more effective to control the interest rate to reduce the exchange rate volatility because the interest rate differential explains more of the forecast decomposition. In the long run, however, the price level becomes a dominant factor in the determination of the exchange rate. Therefore, the control of money supply should be given high priority because the interest rate differential becomes exogenous and it only explains a negligible portion of the long-run exchange rate movement.

Appendix

.

Appendix 1: Program Description

Software used:

I have used the following software to test the hypotheses, estimate the equations and depict the graphs.

1. Regression Analysis of Time Series (RATS) of version *5.11*, *Estima* Company (2002).

2. Cointegration Analysis of Time Series (CATS) of version *1.03*; *Estima* Company (2002).

Software Manual:

I have consulted the following three books to write and run the programs.

1. "RATS User's Guide" (version 5, 2002), *Estima* Company.

2. "Rats Reference Manual" (version 5, 2002), *Estima* Company.

3. "RATS Handbook For Econometric Time Series" (1996), Water Enders, John Wiley & Sons, Inc.

Appendix 2: Data Source and Description

Data Source:

Short Run(Jan.1973　Jun. 2004, monthly): DataStream and the author's calculation (data on the first day of each month)

Long Run(Year 1870　Year 2003,annually): Global Financial Data, Incorporation. Directory of "Sample Data Access" on http://www.globalfindata.com/ (Sections of "Commodity Prices", "Exchange Rates", and "Interest Rates" of U.S. and Japan).

Data Description:

S: yen/dollar exchange rate (New York market buying rates for the short run; close rates on the last day of each year for the long run).

IJ: Japanese nominal interest rate level (euro rates in London market for the short run; 7-year government bond rate for the long run);

IU: U.S. nominal interest rate level (euro rates in London market for the short run; 10-year government bond rate for the long run);

PU: U.S. consumer price index (CPI);

PJ: Japanese consumer price index;

INFU: U.S. inflation level (calculated from "PU");

INFJ: Japanese inflation level (calculated from "PJ");

RIU: U.S real interest level (calculated from "IU" and "INFU");

RIJ: Japanese real interest level (calculated from "IJ" and "INFJ").

Appendix 3: Data Summary

Appendix 3.1: Short Run

Series	Obs	Mean	Std Error	Minimum	Maximum
S	377	176.567533	67.484020	83.690000	305.67000
IU	353	0.070099	0.036694	0.010313	0.193750
IJ	311	0.037805	0.032370	-0.005000	0.144375
PU	376	219.346888	78.871551	78.681454	347.01170
PJ	376	155.058245	30.585180	67.300000	186.60000
INFJ	376	0.034114	0.050785	-0.016000	0.251000
INFU	376	0.049125	0.032070	0.011000	0.148000
RIU	351	0.024031	0.025832	-0.044500	0.090375
RIJ	309	0.022462	0.020216	-0.042250	0.069125

Appendix 3.2: Long Run

Series	Obs	Mean	Std Error	Minimum	Maximum
S	134	107.617443	140.804934	0.902700	360.0000
PJ	134	23.806538	35.651962	0.018500	101.3000
PU	134	40.087280	49.057558	6.762000	184.3000
IJ	134	0.058510	0.021692	0.005400	0.148200
IU	134	0.045743	0.023343	0.016700	0.139800

Appendix 4: Short-Run Forecast Error

Appendix 4.1: 5 Step Ahead Forecast Error

.

Responses to Shock in Δs_{t+1}

Entry	Δs_{t+1}	$\Delta(p_t - p_t^*)$	$\Delta(i_t - i_t^*)$
1	0.0269163	-0.0003734	0.0006010
2	0.0102160	-0.0007288	-0.0006404
3	0.0011473	-0.0000850	-0.0005743
4	-0.0004385	0.0001329	-0.0002220
5	-0.0001759	0.0000187	-0.0000339

Responses to Shock in $\Delta(p_t - p_t^*)$

Entry	Δs_{t+1}	$\Delta(p_t - p_t^*)$	$\Delta(i_t - i_t^*)$
1	0.0000000	0.0046116	-0.0001098
2	0.0002941	0.0002763	-0.0003239
3	-0.0000268	-0.0009620	0.0001913
4	-0.0000195	-0.0000973	0.0001075
5	-6.6473524e-06	0.0002028	-0.0000349

Responses to Shock in $\Delta(i_t - i_t^*)$

Entry	Δs_{t+1}	$\Delta(p_t - p_t^*)$	$\Delta(i_t - i_t^*)$
1	0.0000000	0.0000000	0.0082958
2	0.0011300	0.0008391	0.0010996
3	-0.0010072	0.0002299	-0.0000398
4	-0.0007153	-0.0001086	0.0000319
5	-0.0001795	-0.0000391	0.0000532

Appendix 4.2: Forecast Error Decomposition

Decomposition of Variance for Series Δs_{t+1}

Step	Std Error	Δs_{t+1}	$\Delta(p_t - p_t^*)$	$\Delta(i_t - i_t^*)$
1	0.026916326	100.000	0.000	0.000
2	0.028813520	99.836	0.010	0.154
3	0.028853951	99.714	0.010	0.275
4	0.028866154	99.653	0.011	0.336
5	0.028867249	99.649	0.011	0.340

Decomposition of Variance for Series $\Delta(p_t - p_t^*)$

Step	Std Error	Δs_{t+1}	$\Delta(p_t - p_t^*)$	$\Delta(i_t - i_t^*)$
1	0.004626714	0.651	99.349	0.000
2	0.004766341	2.952	93.949	3.099
3	0.004868629	2.859	93.947	3.193
4	0.004872624	2.929	93.833	3.238
5	0.004877036	2.925	93.837	3.238

Decomposition of Variance for Series $\Delta(i_t - i_t^*)$

Step	Std Error	Δs_{t+1}	$\Delta(p_t - p_t^*)$	$\Delta(i_t - i_t^*)$
1	0.008318276	0.522	0.017	99.461
2	0.008421267	1.088	0.165	98.748
3	0.008443089	1.545	0.215	98.240
4	0.008446750	1.612	0.231	98.156
5	0.008447058	1.614	0.233	98.153

.

Appendix 5: Long-Run Forecast Error Decomposition

Decomposition of Variance for Series s_{t+1}

Step	Std Error	s_{t+1}	$(p_t - p_t^*)$	$(i_t - i_t^*)$
1	0.189581258	100.000	0.000	0.000
2	0.309738550	93.192	6.789	0.019
3	0.432056884	88.129	11.849	0.021
4	0.551653765	88.619	11.343	0.037
5	0.654340285	90.030	9.869	0.101

Decomposition of Variance for Series $(p_t - p_t^*)$

Step	Std Error	s_{t+1}	$(p_t - p_t^*)$	$(i_t - i_t^*)$
1	0.114828590	13.133	86.867	0.000
2	0.243369338	33.845	66.096	0.059
3	0.364040946	49.553	50.328	0.119
4	0.463896056	58.664	40.993	0.343
5	0.546091937	64.297	35.020	0.683

Decomposition of Variance for Series $(i_t - i_t^*)$

Step	Std Error	s_{t+1}	$(p_t - p_t^*)$	$(i_t - i_t^*)$
1	0.010359720	0.353	0.375	99.272
2	0.011577120	0.492	1.463	98.045
3	0.012845670	1.522	2.139	96.340
4	0.013825069	2.737	2.572	94.692
5	0.014661782	4.417	3.185	92.398

References

Abuaf, Niso and Philippe Jorion (1990), "Purchasing Power Parity in the Long Run," *Journal of Finance* 45: 157-74.

Adler, Michael and Bruce Lehmann (1983), "Deviations from Purchasing Power Parity in the Long Run," *Journal of Finance* 38: 1471-87.

Akaike, Hirotugu (1974), "A New Look at the Statistical Model Modification," *IEEE Transactions on Automatic Control,* AC-19: 716-23.

Alexius, Annika(2001), "Uncovered Interest Parity Revisited," *Review of International Economics* 9(3): 505-17.

Baum, Christopher F., John T. Barkoulas, and Mustafa Caglayan (2001), "Nonlinear Adjustment to Purchasing Power Parity in the post-Bretton Woods Era," *Journal of International Money and Finance* 20:379-99.

Bec, Frederique Melika Ben Salem, and Marine Carrasco (2004), "Test for Unit-Root versus Threshold Specification with an Application to the PPP," *Journal of Business & Economic Statistics* 22 (4): 382-95.

Black, Fisher (1986), "Noise," *Journal of Finance* 41: 529-43.

Campbell, John Y. and Pierre Perron (1991), "Pitfalls and Opportunities: What Macroeconomists Should Know about Unit Roots," *NBER Macroeconomic Annual*: 143-201.

Campbell, John Y. and Richard H. Clarida (1987), "The Dollar and Real Interest Rates," *Carnegie-Rochester Conference Series on Public Policy* 27: 103-40.

Caporale, Guilielmo, Sarantis Kalyvitis and Nikitas Pettis (2001), "Testing PPP and UIP in a FIML Framework: Some Evidence for German and Japan," *Journal of Policy Modeling* 23: 637-650.

Cassel, Gustav (1921), "The World's Monetary Problems," London: Constable.

Cavallo, Michele and Fabio Ghironi (2002), "Net Foreigh Assets and the Exchange Rate: Redux Revived," *Journal of Monetary Economics* 49 1057-1097.

Cheng, Benjamin S. (1999), "Beyond the Purchasing Power Parity: Testing for Cointegration and Causality between Exchange Rates, Prices, and Interest Rates," *Journal of International Money and Finance* (18): 911-924.

Coakley, Jerry, Robert P. Flood, and Mark P. Taylor (2003), "Testing Long-Run Relative Purchasing Power Parity," mimeo, University of Warwick.

De Long, J. Bradford, Andrei Shleifer, Lawrence H. Summers, and Robert J. Waldman (1990), "Noise Traders Risk in Financial Markets," *Journal of Political Economy* 98: 703-38.

Dornbush, Rudiger (1976), "Expectations and Exchange Rate Dynamics," *Journal of Political Economy* 84: 1161-76.

Edison, Hali J.(1987), "Purchasing Power Parity in the Long Run," *Journal of Money, Credit and banking* 19: 376-87.

Enders, Walter (1995), Applied Econometric Time Series, John Wiley & Sons, Inc.

—— (1996), "RATS Handbook For Econometric Time Series", John Wiley & Sons, Inc.

Engel, Charles (1996), "The Forward Discount Anomaly and the Risk Premium: A Survey of Recent Evidence," *NBER Working Papers.*

Engel, Charles and James C. Morley (2001), "The Adjustment of Prices and the Adjustment of Exchange Rate," *NBER Working Papers*.

Engel, Charles and John H. Rogers (1996), "How Wide is the Border," *American Economic Review* 86: 1112-25.

Engle Robert F., David M. Lilien, and Russel P. Robins (1987), "Estimating Time Varying Risk Premia in the Term Structure: The ARCH-M model," *Econometrica* 55: 391-407.

Engle, Robert E. and Clive-W.J. Granger (1987), "Cointegration and Error-Correction: Representation, Estimation, and Testing," *Econometrica* 55: 251-76.

Fisher, Eric (2001), "Purchasing Power Parity and Interest Parity in the Laboratory," *Working Papers of Ohio State University, Department of Economics*.

Frankel, Jeffrey A. (1986), "International Capital Mobility and Crowding out in the US Economy" in R.W. Hafer(Ed.), How Open is the US Economy? Lexington: Lexington Books.

Frankel, Jeffrey A. and Andrew K.Rose (1996), "A Panel Project on Purchasing Power Parity: Mean Reversion Within and Between Countries," *Journal of International Economics* 40:209-24.

Frenkel, Jacob A. (1978), "Purchasing Power Parity: Doctrinal Perspective and Evidence from the 1920s," *Journal of International Economics* 8: 169-91.

Froot, Kenneth A. and Kenneth Rogoff (1995), "Perspectives on PPP and Long-Run Real Exchange Rates," in Kenneth Rogoff and Gene Grossman (eds.), Handbook of International Economics, Amsterdam: North-Holland.

Froot, Kenneth A., Michael Kim, and Kenneth Rogoff (1995), "The Law of One Price Over 700 Years," *NBER Working Paper*.

Gokcan, Aysun and Erdal Ozmen (2002), "Do PPP and UIP Need Each Other In a Financially Open Economy? The Turkish Evidence," *ERC Working Papers in Economics*.

Granger, Clive W.J and Paul Newbold (1974), "Spurious Regression in Econometrics," *Journal of Econometrics* 2: 111-120.

Hansen, Lars Peter and Robert J. Hodrick (1980), "Forward Rates As Unbiased Predictors of Future Spot Rates," *Journal of Political Economy* 88: 829-53.

Hau, Harald (2000), "Exchange Rate Determination: The Role of Factor Price Rigidities and Nontradeables," *Journal of International Economics* 50(2): 1-16.

Im, Kyung So, M. Hashem Pesaran, and Yongcheol Shin (1997), "Testing for Unit Roots in Heterogeneous Panels," *Working Papers Series*, University of Cambridge.

Isard, Peter (1977), "How Far Can We Push the 'Law of One Price'?" *American Economic Review* 67(5): 942-48.

Johansen, Soren and Katarina Juselius (1992), "Testing Structural Hypothesis in a Multivariate Cointegration Analysis of the PPP and the UIP for the UK," *Journal of Econometrics* 53: 211-44.

Juselius, Katarina (1991), "Long-run relations in a well defined statistical model for the data generating process: Cointegration analysis of the PPP and the UIP relations for Denmark and Germany," In Gruber, J (ed.): *Econometric Decision models: New Methods of Modeling and Applications*. Springer Verlag.

Juselius, Katarina and Ronald MacDonald (2000), "International Parity Relationship between Germany and the United States," Unpublished report, European University Institute.

Kim, Jaebeom and Masao Ogaki (2004), "Purchasing Power Parity for Traded and Non-Traded Goods: A Structural Error Correction Approach," *Monetary and*

Economic Studies 22, 1-25.

Krasher, William S. (1980), "The 'Peso Problem' in Testing the Efficiency of Forward Exchange Markets," *Journal of Monetary Economics* 6: 269-76.

Levin, Andrew and Chien Fu Lin (1993), "Unit Root Tests in Panel Data: New Results," University of California, San Diego, Department of Economics Working Paper.

Lewis, Karen K. (1989), "Changing Beliefs and Systematic Rational Forecast Errors with Evidence from Foreign Exchange," *American Economic Review* 79: 621-36.

Lothian, James R. and Mark P. Taylor (1997), "Real Exchange Rate Behavior: the Problem of Power and Sample Size," *Journal of International Money and Finance* 16: 945-54.

——(1996), "Real Exchange Rate Behavior: the Recent Float from the Perspective of the Past Two Centuries," *Journal of Political Economy* 104: 488-510.

MacDonald, Ronald (2000), "Concepts to Calculate Equilibrium Exchange Rates: An Overview," *Discussion Paper of Economic Research Group of the Deutsche Bundebank*.

Maddala, G.S. and Shaowen Wu (1999), "A Comparative Study of Unit Root Tests with Panel Dataand a New Simple Test," *Oxford Bulletin of Economics and Statistics* 61: 631-52.

Mark, Nelson C. (2001), International Macroeconomics and Finance, Blackwell Publisher Ltd, UK.

Mark, Nelson C. and Yangru Wu (1998), "Rethinking Deviations from Uncovered Interest Parity: The Role of Covariance Risk and Noise," *Economic Journal* *108*: 1686-706.

Meese, Richard and Kenneth Rogoff (1988), "Was It Real? The Exchange Rate-Interest Rate Differential Relation Over the Modern-Floating Period," *Journal of Finance* 43: 933-48.

Meredith, Guy and Menzie D. Chinn (1998), "Long-Horizon Uncovered Interest Rate Parity," *NBER Working Papers*.

Obstfeld, Maurice and Kenneth Rogoff (1995), Foundations of International Macroeconomics, MIT press, London.

——(1996), "Exchange Rate Dynamics Redux," *Journal of Political Economy* 103(3): 624-660.

Officer, Lawrence H. (1976), "The Purchasing-Power-Parity Theory of Real Exchange Rates," *IMF Working Paper.*

Ogaki, Masao (1999), "A Theory of Exchange Rates and the Term Structure of Interest Rates," *Working Papers of Ohio State University, Department of Economics.*

Papell, David H. and Ruxandra Prodan (2004), "Long Run Purchasing Power Parity: Cassel or Balassa- Samuelson?," *Working Paper of University of Houston.*

Phillips, Peter C.B. and Pierre Perron (1988), "Testing for a Unit Root in Time Series Regression," *Biometrica* 75: 335-46.

Reinhart, Carmen M. and Kenneth Rogoff (2002), "The Modern History of Exchange Rate Arrangements: A Reinterpretation," *NBER Working Paper Series.*

Rogoff, Kenneth (1996), "The Purchasing Power Parity Puzzle," *Journal of Economic Literature* 34: 647-68.

Roll, Richard (1979), "Violations of Purchasing Power Parity and Their

Implications for Efficient International Commodity Markets," in Sarnat M. and Szego.G.P. (eds.), International Finance and Trade, Cambridge, Ballinger.

Samuelson, Paul A. (1964), "Theoretical Notes on Trade Problems," *Review of Economics and Statistics* 46: 145-54.

Sarno, Lucio and Mark P. Taylor (2002), "Purchasing Power Parity and the Real Exchange Rate," *IMF Staff Papers* 49(a): 65-105.

Schwarz, Gideon (1978) "Estimating the Dimension of a Model", *Annals of Statistics*, 6, 461-464.

Sims, Christopher (1980), "Macroeconomics and Reality," *Econometrica* 48: 1-49.

Stephens, Dominick (2004), "The Equilibrium Exchange Rate According to PPP and UIP," *Reserve Bank of New Zealand, Discussion Paper*.

Taylor, Mark P., David Peel, and Lucio Sarno (2001), "Nonlinear Mean-Reversion in Real Exchange Rates: Towards a Solution to the Purchasing Power Parity Puzzles," *International Economic Review* 42: 1015-42.

Wu, Yangru (1996), "Are Real Exchange Rate Non-Stationary? Evidence from a Panel-Data Test," *Journal of Money Credit and Banking* 28:54-63.