Real Exchange Rates – Real Interest Rates Differentials Relationship in Korean Won vs US Dollar Before & After the East Asian Financial Crisis: 1991~2011

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Abstract

In this study, I extend the studies of Meese and Rogoff (1998) and others to find a stable long-run relationship between real exchange rates and real interest rates differentials using Korean Won/US Dollar data for the period of 1991~2011 containing the East Asian financial crisis. Applying error correction model to two sub-periods before and after the crisis, I could identify a reliable relationship between the two variables with the addition of foreign exchange reserves for the post-crisis period but not for the pre-crisis period. The estimate of the coefficient on the real interest rates differential is significant but positive unlike the prediction of conventional interest rate parity theory. However, the sign is negative and significant on the lagged real interest differential. Korean foreign exchange reserve is estimated to have a negative significant effcet on the Won/USD real exchange rate.

JEL classification: F3, C2

Keywords: real exchange rate, real interest rates differential, foreign exchange reserve, error correction model, interest parity

I. Introduction

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Numerous studies on the relation between real exchange rates and real interest rate differentials fail to show any statistically significant cointegration relationship for the two variables, especially when using single equation method of Johansen (1988) (e.g., Meese and Rogoff, 1988; MacDonald and Nagayasu, 1999) or when using data for advanced countries like G7 countries (e.g., Chortareas and Driver, 2001). More recent studies changed this negative stream and showed more positive results by way of panel cointegration method (e.g., MacDonald and Nagayasu, 1999), in terms of small open economies (e.g., Chortareas and Drive, 2001), using extra variables such as foreign reserves (e.g., Narayan and Smyth, 2006), or in terms of volatilty regime linkages (e.g., Kanas, 2005).

Kaen et al (1984) examine the effects of interest rate news on changes in forward foreign exchange rates using data for seven advanced countries including British pound, Canadian dollar, German mark, Dutch guilder, French franc, Japanese yen, and Swiss franc for 1976~1981. They find that interest rate forecasting errors do not explain the errors in forecasting forward exchange rates and confirm the conjecture that the forward exchange rate is not an estimate of the expected spot exchange rate. Meese and Rogoff (1988) confirm that real interest differentials are not highly correlated with real exchange rate movements in a study using data for Dollar/Mark, Dollar/Pound, and Dollar/Yen for 1974~1985. Following unit root tests, Meese and Rogoff (1988) find that real exchange rates and long-term real interest differentials are nonstationary but short-term real interest differentials are not nonstationary. However, they could not reject the hypothesis of no cointegration between real exchange rates and real long-term interest differentials. This lack of cointegration relationship, in their opinion, might be due to the omission of relevant variables from the relationship, especially real shocks such as productivity disturbances.

Ensuing studies, Edison and Pauls (1993), Johansen and Juselius (1992), Edison and Melick (1999), MacDonald and Nagayasu (1999), Chortareas and Driver (2001) among others, to find cointegration relationship between real exchange rate and real interest rate differential have shown mixed results, often unable to reject the null hypothesis of no cointegration. Edison and Pauls (1993) use cointegration test and error correction models to examine the link between real exchange rates and real interest rate differentials. Their specification of dynamic model using error correction mechanism shows that the level of real interest rate differential is statistically significant based on the null hypothesis of cointegration. However, this result cannot be supported as their test of cointegration suggested that there was no simple long-run relationship between real exchange rates and real interest rate differentials. MacDonald and Nagayasu (1999) find statistically significant long-run relationship between real exchange rates and real interest rate differentials for the floating exchange rate period of 1976Q1-1997Q4 using a panel cointegration method for 14 industrialized countries. However, MacDonald and Nagayasu (1999) could not find a strong long-run relationship between the two variables when using the single country equation method of Johansen (1988). Chortareas and Driver (2001) employ non-stationary panel techniques and derive positive empirical evidence of long-run cointegration relationship between real exchange rates and real interest rate differentials for the group of eleven small open economies, all of which are OECD countries, for the period of 1978Q2 to 1998Q4. This positive relation however does not obtain for the group of G7 countries. In studying this, Chortareas and Driver (2001) use two major theories in international macroeconomics, i.e. the relative purchasing power parity (PPP) and the uncovered interest parity (UIP).

Narayan and Smyth (2006) identify the cointegration relationship among real exchange rate, foreign exchange reserves and real interest rate differential using 1980~2002 Chinese monthly data with respect to the US dollar. Narayan and Smyth (2006) also find that in the long run real exchange rate has a significant positive effect on foreign exchange reserves. Bergin and Sheffrin (2000) develop a testable intertemporal model of current account with variable interest rates and exchange rates to account for external shocks to small open economies. They find that their model with these additional variables fit the data much better graphically as well as statistically than the benchmark model without those variables. Their results fare well for Australia and Canada but not for the United Kingdom for the periods of 1960Q1 (1961Q2 for Australia) to 1996Q2. This might be due to the different status of the UK in the international financial market as a major player. Kanas (2005) adopts Markov Switching Vector Autoregressive (MS-VAR) model to identify the regime linkage between the US/UK real exchange rate and real interest differential for 1921~2002 data. Kanas (2005) finds that the periods of high volatility regime coincide with the periods of floating exchange rates, while the periods of low volatility regime roughly coincide with the Gold Exchange Standard and Bretton Woods periods of fixed exchange rates. He also shows that these volatility regimes occur concurrently for the two variables of real exchange rates (in changes, and also in levels) and real interest differentials and thereby establishes a regime linkage between the two variables in terms not of level values but of volatilities.

Section II describes the base model and Section III explains data source and construction. Section IV exercises unit root test and cointegration test on the ingredient variables. Section V illustrates scatter plots of real exchange rate and real interest rates differential and checks the structural break across the East Asian financial crisis. Section VI runs regressions using error correction model and Section VII concludes.

II. Model

The main model of this study closely follows that of Meese and Rogoff (1988). There are three main building blocks.[2] First, any temporary deviation of the real exchange rate due to some external shocks from its flexible-price equilibrium value vanishes monotonically at a

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[2] They come originally from Dornbusch (1976), Frankel (1979), and Hooper and Morton (1982).

constant rate.

$$E_t\,(q_{t+k}-\overline{q_{t+k}}) = \theta^k\,(q_t-\overline{q_t}), \qquad 0<\theta<1 \tag{1}$$

where E_t is the time t expectations operator, $q_t \equiv s_t + p_t^* - p_t$, s_t is logarithm of nominal exchange rate, p_t is logarithm of domestic price level, p_t^* is logarithm of foreign price level, $\overline{q_t}$ is flexible-price equilibrium value of q_t, and θ is the speed of adjustment parameter.[3] Second, the *ex ante* purchasing power parity under flexible prices holds.

$$E_t\,\overline{q_{t+k}} = \overline{q_t} \tag{2}$$

Equation (2) implies that $\overline{q_t}$ is either constant or a random walk. Third, the uncovered interest parity relation holds.

$$E_t s_{t+k} - s_t = {}_k r_t - {}_k r_t^* \tag{3}$$

where ${}_k r_t$ is the *k*-period nominal interest rate at time t.

We define *k*-period real interest rate as ${}_k R_t \equiv {}_k r_t - (E_t p_{t+k} - p_t)$.

Then we get from (3),

$$E_t q_{t+k} - q_t = {}_k R_t - {}_k R_t^* \tag{4}$$

Substituting (2) and (4) into (1), we get

$$q_t = \alpha\,({}_k R_t - {}_k R_t^*) + \overline{q_t} \tag{5}$$

where $\alpha = 1/(\theta^k - 1) < -1$. Equation (5) is the fundamental relationship between the real exchange rate and the real interest rates differential with additional flexible-price real exchange rate value.

III. Data

[3] Variables with * indicate corresponding foreign variables.

We use monthly data for nominal exchange rates and consumer price index from IMF eLibrary (http://elibrary-data.imf.org/), 1-year monetary stabilization bond (MSB) rates and 91-day CD rates from the Bank of Korea Economic Statistics system (http://ecos.bok.or.kr/), and 1-year treasury bond rates and 3-month CD rates from the US Federal Reserve system Economic Research & Data (http://www.federalreserve.gov/).[4] We convert nominal exchange rates and nominal interest rates into real exchange rates and real interest rates using consumer price indices of the corresponding countries. We focus on 1-year bond rates data but we will also mention the results from 3-month interest rates in due course.

We have $Q_t = S_t P_t^* / P_t$ where Q_t is real exchange rate, S_t is nominal exchange rate in units of home currency per unit of foreign currency, P_t^* is foreign price level (consumer price index), and P_t is home price level. The *k*-period real interest rate is defined as ${}_kR_t \equiv {}_kr_t - (E_t p_{t+k} - p_t)$, but we use actual price level p_{t+k} instead of expected price level $E_t p_{t+k}$ due to lack of data. Hence, we use ${}_kR_t = {}_kr_t - (\log P_{t+k} - \log P_t)$ where log is a natural logarithm.

Let us run here the regression on (5) as below.

$$q_t = \alpha_0 + \alpha_1 ({}_kR_t - {}_kR_t^*) + \varepsilon_t \tag{6}$$

We get the regression results using 1-year bond rates as below with standard errors in the parentheses for 1991M01(January)~2011M07(July).[5]

$$\underset{(15.700)}{q_t = 1150.465} - \underset{(2.941)}{15.350} ({}_kR_t - {}_kR_t^*) \tag{7}$$

[4] Korean 91-day CD rates are available from 1991 March whereas 91-day CP rates are available only from September 1994 from Bank of Korea Economic Statistics system while the US 3-month CD rates are available from 1964 June whereas 3-month CP rates are available only from 1997 January from the US Federal Reserve System.

[5] Details are available from the author on request. We use E-Views 6 for regression and relevant tests in this study.

$R^2 = 0.11$, $DW = 0.078$, $SER = 165.76$

The results in (7) seem to suggest that there is a close relationship between real exchange rate and real interest rates differential as indicated by the strongly statistically significant coefficient of α_1.

IV. Stationarity and Cointegration Test

4.1 Stationarity Test

Before we go further with regressions, we need to check stationarity of relevant variables. We define the whole period as 1991M01~1997M10 + 1998M08~2011M07, pre-crisis period as 1991M01~1997M10 (Period I), and post-crisis period as 1998M08~2011M07 (Period II), dropping erratic months of 1997M11~1998M07. Carrying out augmented Dickey-Fuller (ADF) unit root tests on Korean won/US dollar real exchange rate for the whole period with a constant, we find that q_t has a unit root and its first difference is stationary at 1% level. In the same way, the real interest rate differential between Korea and the US, ${}_kR_t - {}_kR_t^*$ for k = 3 months and k = 1 year, we find that it has also a unit root but the first difference is stationary for both maturities except 1-year bond rates data for period II, the series of which is already stationary for period II. We summarize the ADF unit root test results in Table 1.

[Table 1] ADF Unit Root Test Results

Variable	**Differencing**	**Whole Period**	**Period I**	**Period II**
RWD	Level	Nonstationary	Nonstationary	Nonstationary
	1st difference	Stationary**	Stationary**	Stationary**
RID3M	Level	Nonstationary	Nonstationary	Nonstationary
	1st difference	Stationary**	Stationary**	Stationary**
RID1Y	Level	Nonstationary	Nonstationary	Stationary*
	1st difference	Stationary**	Stationary**	Stationary**

RSV^K	Level	Nonstationary	Nonstationary	Nonstationary
	1st difference	Stationary**	Stationary**	Stationary**
RSV^{US}	Level	Nonstationary	Nonstationary	Nonstationary
	1st difference	Stationary**	Stationary**	Stationary**

** indicates significance at 1% level and * indicates significance at 5% level, respectively.

In Table 1, $RWD = Q = SP^* / P$ is Won/Dollar real exchange rate, $RID3M$ is real interest rates differential between Korean 91-day CD rates and the US 3-month CD rates, both of which are adjusted by corresponding CPI inflation rates, $RID1Y$ is real interest rates differential between Korean 1-year MSB (monetary stabilization bond) rates and the US 1-year treasury bill rates. We also check the stationarity of RSV^K and RSV^{US}, foreign exchange reserves of Korea and the US, for later use. Overall, we can say that RWD, $RID3M$, RSV^K, and RSV^{US} are all integrated of order one, i.e. I (1). $RID1Y$ is also I (1) for the whole period and period I, but is I (0) for period II.

4.2 Cointegration Test

Following the stationarity check above, we carry out Johansen cointegration test among the relevant variables. We find that the two variables RWD and RID_k are not cointegrated at any significance level for the whole period and also for period I with either 3-month CD rates or 1-year bond rates.[6] However, RWD and RID_k are cointegrated at least at 5% significance level with both maturities for period II. The result for { $RWD, RID1Y$ } for period II is somewhat dubious because RWD is I (1) and $RID1Y$ is I (0) for that period in Table 1. Even when we add variables RSV^K and RSV^{US} (foreign exchange reserves of Korea and the US), the four variables are still not cointegrated for the whole period and only weakly cointegrated for period I with 1-year bond rates. RWD, RID_k, RSV^K and RSV^{US} are

[6] Details are available from the author on request.

strongly cointegrated for period II with either maturity.[7] We show the Johansen cointegration test results in Table 2.

[Table 2] Johansen Cointegration Test Results

Variables Set	**Whole Period**	**Period I**	**Period II**
{ $RWD, RID3M$ }	Not cointegrated	Not cointegrated	Cointegrated**(*)[a]
{ $RWD, RID3M$, RSV^{K}, RSV^{US} }	Not cointegrated	Not cointegrated	Cointegrated**
{ $RWD, RID1Y$ }	Not cointegrated	Not cointegrated	Cointegrated**
{ $RWD, RID1Y$, RSV^{K}, RSV^{US} }	Not cointegarted	Cointegrated(*)[b]	Cointegrated**[c]

** indicates significance at 1% level and * indicates significance at 5% level, respectively.

a: Johansen cointegration test shows significance at 1% level for trace test and significance at 5% for maximum eigenvalue test.

b: Johansen cointegration test shows significance at 10% level for trace test and significance at 5% for maximum eigenvalue test.

c: The result is the same when we use only three variables of RWD, RSV^{K}, and RSV^{US}.

The results in Table 2 imply that the Won/Dollar real exchange rate and real interest rates differentials between Korea and the US have certain long-run relationship after the East Asian financial crisis but not before the crisis. For the period before 1997, even the addition of foreign exchange reserves do not explain efficiently the movements of real exchange rates or real interest differentials. There must be some other variables that affect the movements of these variables before the crisis. This outcome also indicates that there has been a structural change in the relationship between real exchange rates and real interest rates differentials across the crisis. We know that Korean financial market was not very highly integrated into the global financial market before the crisis and it became much more closely coupled with the global market after the crisis.

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7 Details are available from the author on request.

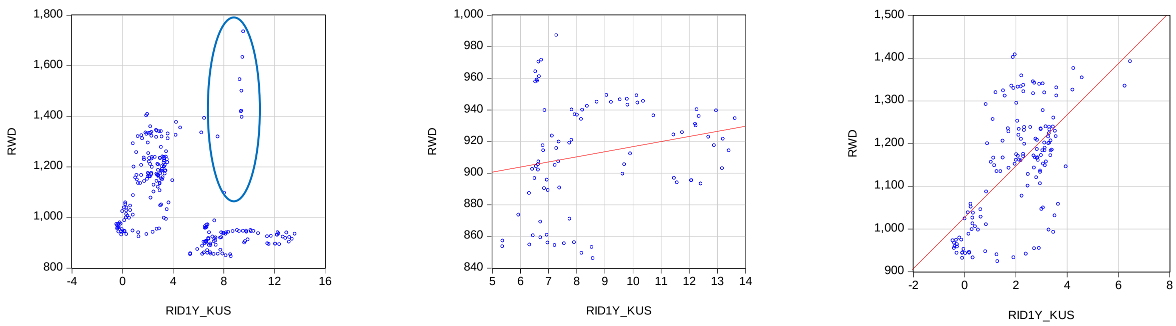
V. East Asian Financial Crisis and Structural Break

In this section, we check whether there was a structural break in the relation between Won/USD real exchange rates and Korea-US real interest rates differentials around the East Asian financial crisis.

5.1 Scatter Plots

First, we show scatter plots of the real exchange rate (RWD) and real interest rates differential ($RID1Y$) for the sample period of 1991M01~2011M07 in Figure 1.

[Figure 1] Scatter Plots of Real Exchange Rates vs Real Interest Rates Differentials



(a) 1991M01~2011M07 (b) 1991M01~1997M10 (c) 1998M08~2011M07

We can see in panel (a) of Figure 1 that the relations between RWD and $RID1Y$ are not uni-modal and they may be clustered into two groups; first, in the bottom right corner with relatively low real exchange rates of ₩800/$~₩1,000/$ and relatively large real interest rates differentials of 5%~14%, and second, in the left side with relatively high real exchange rates of ₩900/$~₩1,400/$ and relatively small real interest rates differentials of -1%~7%. The nine isolated outliers inside an ellipse in the upper right quarter belong to the high tide of East Asian financial crisis of 1997M11~1998M07 between the two subsample periods with high real exchange rates and relatively large real interest rates differentials.

The scatter plots for the two sub-periods are drawn in panel (b) for the pre-crisis and panel (c) for the post-crisis in Figure 1. The correlation coefficient between RWD and $RID1Y$ equals 0.217 for 1991M01~1997M10 before the EAFC and 0.618 for 1998M08~2011M07 after the EAFC.[8] Moreover, the regression lines of panels (b) and (c) in Figure 1 indicate much steeper slope for the post-crisis period with about ₩60/USD/% than for the pre-crisis period with about ₩3.3/USD/%. Naively speaking, this means that the sensitivity of Won/USD real exchange rate with respect to real interest rates differential became much stronger (about 18 times) after the EAFC. Figure 1 seems to justify the structural break test and we carry out Chow test accordingly.

5.2 Chow Structural Break Test

We run regression (6) using 1-year bond rates for the three samples of (i) pooled; 1991M01~1997M10 + 1998M08~2011M07, (ii) period I; 1991M01~1997M10, and (iii) period II; 1998M08~2011M07 and get RSS (residual sum of squares) for each regression as below.[9]

(i) Pooled: 1991M01~1997M10 + 1998M08~2011M07

$$\underset{}{RWD_t = \underset{(15.819)^{**}}{1161.345} - \underset{(2.031)^{**}}{21.721}\, RID1Y_t} \tag{8.1}$$

$R^2 = 0.253, \quad DW = 0.046, \quad RSS = 4{,}168{,}822$

(ii) Period I: 1991M01~1997M10

$$RWD_t = \underset{(13.803)^{**}}{884.577} + \underset{(1.316)^{*}}{3.224}\, RID1Y_t \tag{8.2}$$

$R^2 = 0.047, \quad DW = 0.055, \quad RSS = 91{,}951.77$

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[8] The correlation coefficient for the whole period of 1991M01~2011M07 is -0.503.
[9] When we use 3-month interest rates instead, the results are qualitatively the same.

(iii) Period II: 1998M08~2011M07

$$RWD_t = 1027.451 + 60.047\, RID1Y_t \qquad (8.3)$$
$$(12.172)^{**} \quad (4.701)^{**}$$

$R^2 = 0.382, \quad DW = 0.101, \quad RSS = 1{,}554{,}076$

** indicates significance at 1% level and * indicates significance at 5% level, respectively.

The F-statistic is given by with t = 226 and k = 2,

$$F(k, t-2k) = \frac{(RSS_P - RSS_I - RSS_{II})/k}{(RSS_I + RSS_{II})/(t-2k)} = \frac{(4168822 - 91951.77 - 1554076)/2}{(91951.77 + 1554076)/222} = 170.12\,.$$

The critical value of F-statistic with 2 and 222 degrees of freedom equals 7.13 at 0.1% significance level. Hence, the null hypothesis of no structural break in the relationship between RWD and $RID1Y$ is flatly rejected.

VI. Error Correction Model

Taking account of the results in Sections IV and V, we propose an ARDL(1,1) (autoregressive distributed lag) model with a period dummy variable $EAFC$, which equals 0 for period I and 1 for period II, slope dummies $EAFC_t \bullet RID\_k_t$ and $EAFC_{t-1} \bullet RID\_k_{t-1}$, and two more regressors of RSV^K and RSV^{US}.[10]

$$\begin{aligned} RWD_t = {} & \beta_0 + \beta_1 RWD_{t-1} + \beta_2 RID\_k_t + \beta_3 RID\_k_{t-1} + \gamma_1 EAFC_t + \gamma_2 EAFC_t \bullet RID\_k_t \\ & + \gamma_3 EAFC_{t-1} \bullet RID\_k_{t-1} + \delta_1 RSV_t^K + \delta_2 RSV_{t-1}^K + \delta_3 RSV_t^{US} + \delta_4 RSV_{t-1}^{US} + \varepsilon_t \end{aligned} \qquad (9)$$

where RID_k is k-period real interest rates differential between Korea and the US, and RSV^K and RSV^{US} are foreign exchange reserves excluding gold in million US dollars of Korea and the US, respectively.

[10] We do not include slope dummies for RSV^K or RSV^{US} for simplicity.

6.1 Cointegrating Relationship

In equilibrium,

(1) Before the crisis,

$$\overline{RWD} = \beta_0 + \beta_1 \overline{RWD} + \beta_2 \overline{RID\_k} + \beta_3 \overline{RID\_k} + \delta_1 \overline{RSV^K} + \delta_2 \overline{RSV^K} + \delta_3 \overline{RSV^{US}} + \delta_4 \overline{RSV^{US}}$$

(period I)

(2) After the crisis,[11]

$$\begin{aligned}\overline{RWD} = {} & \beta_0 + \beta_1 \overline{RWD} + \beta_2 \overline{RID\_k} + \beta_3 \overline{RID\_k} + \gamma_1 + \gamma_2 \overline{RID\_k} \\ & + \gamma_3 \overline{RID\_k} + \delta_1 \overline{RSV^K} + \delta_2 \overline{RSV^K} + \delta_3 \overline{RSV^{US}} + \delta_4 \overline{RSV^{US}}\end{aligned}$$

(period II)

Rearranging these,

$$\overline{RWD} = \frac{\beta_0}{1-\beta_1} + \frac{\beta_2+\beta_3}{1-\beta_1} \overline{RID\_k} + \frac{\delta_1+\delta_2}{1-\beta_1} \overline{RSV^K} + \frac{\delta_3+\delta_4}{1-\beta_1} \overline{RSV^{US}}$$

(period I)

$$\overline{RWD} = \frac{\beta_0+\gamma_1}{1-\beta_1} + \frac{\beta_2+\beta_3+\gamma_2+\gamma_3}{1-\beta_1} \overline{RID\_k} + \frac{\delta_1+\delta_2}{1-\beta_1} \overline{RSV^K} + \frac{\delta_3+\delta_4}{1-\beta_1} \overline{RSV^{US}}$$

(period II).

Hence, we get the following cointegrating relationships,

$$RWD_t = \frac{\beta_0}{1-\beta_1} + \frac{\beta_2+\beta_3}{1-\beta_1} RID\_k_t + \frac{\delta_1+\delta_2}{1-\beta_1} RSV_t^K + \frac{\delta_3+\delta_4}{1-\beta_1} RSV_t^{US}$$

(period I)

(10.1)

$$RWD_t = \frac{\beta_0+\gamma_1}{1-\beta_1} + \frac{\beta_2+\beta_3+\gamma_2+\gamma_3}{1-\beta_1} RID\_k_t + \frac{\delta_1+\delta_2}{1-\beta_1} RSV_t^K + \frac{\delta_3+\delta_4}{1-\beta_1} RSV_t^{US}$$

(period II).

(10.2)

We can see that the short-run effect of RID_k on RWD equals β_2 before crisis and $\beta_2+\gamma_2$ after crisis from (9) and the long-run effect equals $(\beta_2+\beta_3)/(1-\beta_1)$ before crisis and $(\beta_2+\beta_3+\gamma_2+\gamma_3)/(1-\beta_1)$ after crisis from (10.1) & (10.2).

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[11] We ignore the month just before period II, i.e. 2008M07, for which $EAFC$ is not defined.

6.2 Error Correction Model[12]

Subtracting RWD_{t-1} from both sides, subtracting $\beta_2\, RID\_k_{t-1}$, $\gamma_2\, EAFC_{t-1} \bullet RID\_k_{t-1}$, $\delta_1\, RSV^K_{t-1}$, $\delta_3\, RSV^{US}_{t-1}$ from the right-hand side and adding them back in equation (9),

$$\begin{aligned} RWD_t - RWD_{t-1} = {} & \beta_0 + (\beta_1 - 1)\, RWD_{t-1} + \beta_2\, RID\_k_t - \beta_2\, RID\_k_{t-1} + \beta_2\, RID\_k_{t-1} \\ & + \beta_3\, RID\_k_{t-1} + \delta_1 RSV^K_t - \delta_1\, RSV^K_{t-1} + \delta_1\, RSV^K_{t-1} + \delta_2\, RSV^K_{t-1} \\ & + \delta_3\, RSV^{US}_t - \delta_3\, RSV^{US}_{t-1} + \delta_3\, RSV^{US}_{t-1} + \delta_4\, RSV^{US}_{t-1} + \varepsilon_t \end{aligned} \quad \text{(period I)}$$

$$\begin{aligned} RWD_t - RWD_{t-1} = {} & \beta_0 + (\beta_1 - 1)\, RWD_{t-1} + \beta_2\, RID\_k_t - \beta_2\, RID\_k_{t-1} + \beta_2\, RID\_k_{t-1} \\ & + \beta_3\, RID\_k_{t-1} + \gamma_1 + \gamma_2\, RID\_k_t - \gamma_2\, RID\_k_{t-1} + \gamma_2\, RID\_k_{t-1} + \gamma_3\, RID\_k_{t-1} \\ & + \delta_1 RSV^K_t - \delta_1\, RSV^K_{t-1} + \delta_1\, RSV^K_{t-1} + \delta_2\, RSV^K_{t-1} + \delta_3\, RSV^{US}_t - \delta_3\, RSV^{US}_{t-1} + \delta_3\, RSV^{US}_{t-1} \\ & + \delta_4\, RSV^{US}_{t-1} + \varepsilon_t \end{aligned}$$

(period II)

Hence, we get

$$\begin{aligned} \Delta RWD_t = {} & (\beta_1 - 1)\left(RWD_{t-1} - \frac{\beta_0}{1-\beta_1} - \frac{\beta_2 + \beta_3}{1-\beta_1} RID\_k_{t-1} - \frac{\delta_1 + \delta_2}{1-\beta_1} RSV^K_{t-1} - \frac{\delta_3 + \delta_4}{1-\beta_1} RSV^{US}_{t-1} \right) \\ & + \beta_2\, \Delta RID\_k_t + \delta_1\, \Delta RSV^K_t + \delta_3\, \Delta RSV^{US}_t + \varepsilon_t \end{aligned}$$

(period I) (11.1)

$$\begin{aligned} \Delta RWD_t = {} & (\beta_1 - 1)\left(RWD_{t-1} - \frac{\beta_0 + \gamma_1}{1-\beta_1} - \frac{\beta_2 + \beta_3 + \gamma_2 + \gamma_3}{1-\beta_1} RID\_k_{t-1} - \frac{\delta_1 + \delta_2}{1-\beta_1} RSV^K_{t-1} - \frac{\delta_3 + \delta_4}{1-\beta_1} RSV^{US}_{t-1} \right) \\ & + (\beta_2 + \gamma_2)\, \Delta RID\_k_t + \delta_1\, \Delta RSV^K_t + \delta_3\, \Delta RSV^{US}_t + \varepsilon_t \end{aligned}$$

. (period II) (11.2)

We know in equations (11.1) & (11.2) that ΔRWD_t, ΔRID_k_t, ΔRSV^K_t, and ΔRSV^{US}_t are all stationary from Table 1. The first terms in the parentheses on the right-hand side in (11.1) & (11.2) are the error correction components defined in equations (10.1) & (10.2), and hence they are also stationary. When we check stationarity of the error correction components, they turn out to have no unit root for both sub-periods as expected. Therefore, we can run

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[12] Refer to Dougherty (2007, pp.405-406) and Greene (2008, pp.681-693).

regressions on (11.1) & (11.2) using least squares in the standard way.[13] In deriving the cointegrating term, we can use the Engle-Granger (1987) two-step procedure. The error correction components in (11.1) & (11.2) can be obtained from an OLS regression of (9) and by substituting the estimates of coefficients $\beta_0 \sim \beta_3$, $\gamma_1 \sim \gamma_3$, and $\delta_1 \sim \delta_4$ into (10.1) & (10.2). We get the estimates as shown in Table 3 with heteroschedasticity consistent standard errors in the parentheses.

[Table 3] Cointegrating Coefficients Estimates using Equation (9) (1-year bonds)[14]

Cointegrating coefficients	**Estimates (std. error) Period I**	**Estimates (std. error) Period II**
β_0	158.334* (60.626)	-
β_1	0.871** (0.0479)	0.956** (0.0399)
β_2	2.046* (1.006)	-
β_3	-0.253 (0.957)	-
$\beta_0 + \gamma_1$	-	55.886 (49.294)
$\beta_2 + \gamma_2$	-	18.899** (6.323)
$\beta_3 + \gamma_3$	-	-15.880** (5.759)
δ_1 [a]	0.574E-3** (0.177E-3)[b]	-0.436E-2** (0.740E-3)[b]
δ_2 [a]	-	0.433E-2** (0.753E-3)[b]
δ_3 [a]	-1.051E-3** (0.275E-3)[b]	-
δ_4 [a]	-	-

** indicates significance at 1% level and * indicates significance at 5% level, respectively.

a: RSV_{t-1}^{K} and RSV_{t-1}^{US} are not significant in period I whereas RSV_{t}^{US} and RSV_{t-1}^{US} are not significant in period II.

b: E-3 denotes the power 10^{-3}.

Now we can run regressions on (11.1) & (11.2) using the coefficient estimates in Table 3 and we get the following results with heteroschedasticity consistent standard errors in the

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[13] Dougherty (2007, pp.405-406).

[14] We also estimate the corresponding coefficients for 3-month CD rates and show the results in Table A1 in the Appendix. However, the results are less satisfactory and the resulting error correction component is stationary only at 10% level for period I. It is not stationary for period II at any conventional significance level.

parentheses.[15]

$$\Delta RWD_t = -0.125\, ECM_t + 1.725\, \Delta RID1Y_t - 0.000716\, \Delta RSV_t^K - 0.000961\, \Delta RSV_t^{US}$$
$$\quad (0.0264)^{**} \quad (1.0499) \qquad (0.000846) \qquad (0.000412)^{*}$$

$$R^2 = 0.329, \quad DW = 1.798, \quad SER = 6.497 \qquad \text{(Period I) (12.1)}$$

$$\Delta RWD_t = -0.0438\, ECM_t + 18.870\, \Delta RID1Y_t - 0.00437\, \Delta RSV_t^K + 1.68E-5\, \Delta RSV_t^{US}$$
$$\quad (0.0139)^{**} \quad (5.871)^{**} \qquad (0.000736)^{**} \qquad (0.280E-3)$$

$$R^2 = 0.426, \quad DW = 1.561, \quad SER = 24.395 \qquad \text{(Period II) (12.2)}$$

** indicates significance at 1% level and * indicates significance at 5% level, respectively.

In equations (12.1) & (12.2), ECM_t is the error correction component shown as the first term in the parentheses on the right-hand side of (11.1) & (11.2). The result for period I is less satisfactory. are consistent with the Johansen cointegration test results in Table 2. For period I (pre-crisis), the real interest rates differential or Korean foreign exchange reserve does not have a significant effect on the real exchange rate while the US foreign exchange reserve has a negative significant effect on the real Won/Dollar exchange rate. The outcome is more interesting for period II. Real interest rates differential has a positive significant effect on the real exchange rate while Korean foreign exchange reserve has a negative significant effect on RWD. The estimate of the coefficient on $\Delta RID1Y_t$ in (12.2) implies that a 1% point increase in the real interest rates differential leads to a contemporaneous depreciation of about 18.8 won of the Korean currency per US dollar in real terms. The sign may seem to be wrong compared to that of $\alpha = 1/(\theta^k - 1) < -1$ in equation (5). However, considering that the time interval is monthly and the estimate of $\beta_3 + \gamma_3$ is negative at -15.880 in Table 3, we can say that the real interest rates differential last month has a negative

[15] Details are available from the author on request.

significant effect on the real exchange rate this month. Meanwhile, the long-run effect of $RID1Y$ on RWD is estimated to be about ₩68.8/$ from Table 3. That is, the higher real interest rate in Korea over that in the US ultimately leads to a lower value of Korean currency compared to the US dollar for the post-crisis period. The reason for this may be that there are some other factors that affect the Won/Dollar real exchange rates apart from the real interest rates differential or foreign reserves, e.g. the inconvertibility or limited liquidity of the Korean currency or the over-dependency of Korean economy on external trades. The exceptionally low nominal interest rates in most of 2000s in the US, global economic crisis in 2008~2009, and ensuing flight to quality of international capital investment may also had an effect. The coefficient on ΔRSV_t^K is more affirmative indicating that 10 billion dollar increase of Korean foreign reserve makes RWD to fall by about ₩43.7/$, maybe a little larger than comfortably acceptable magnitude. Nevertheless, this supports the conjecture that large volume of foreign exchange reserve buttresses the domestic currency stronger. The coefficient on ECM_t in (12.2) indicates that about 4.38% of the previous period's deviation of the real exchange rate from its flexible price equilibrium level will be corrected in one month. This amounts to 13.7% in 3 months, 29.3% in 6 months, and 67.3% in 1 year.

VII. Conclusion

We have studied the relationship between real exchange rates and real interest rates differentials for Korean won and the US dollar for the period of 1991~2011. We divided the period into two sub-periods; (1) period I (January 1991 to October 1997) before the East Asian financial crisis and (2) period II (August 1998 to July 2011) after the crisis, which broke out in late 1997 and continued to mid 1998. Following ADF unit root tests for the ingredient variables and Johansen cointegration tests among relevant variables, we ran regressions using error correction mechanism. Before the crisis, real interest rates differential did not affect the real exchange rate significantly. After the crisis, real interest rates differential had a positive significant effect and Korean foreign exchange reserve had a negative significant effect on the real exchange rate, respectively. The coefficient on the error correction component had the expected negative sign and reasonable adjustment speed. Overall, the data fitted better the interest rate parity theory for the post-crisis period than before the crisis. This seems reasonable given the states of openness to and integration into the global market of the Korean financial market across the periods.

The real exchange rate is a key factor in determining the competitiveness of a country in a world of closely interlinked economies. International capital flows have accelerated their speed and volume substantially and global financial market is now highly integrated. Nevertheless, the free capital flow and substitutability of financial products across countries do not completely guarantee the satisfaction of interest parity condition. Exchange rate determination mechanism is a complicated process and it requires rigorous theoretical applications as well as experienced expertise combining various factors of the real economy. Even so, it is worth trying to analyze available data with acceptable economic theories to improve the understanding of important relationships such as between the real exchange rate and real interest rates differential.

Appendix

[Table A1] Cointegrating Coefficients Estimates using Equation (9) (3-month CDs)

Cointegrating coefficients	**Estimates (std. error) Period I**	**Estimates (std. error) Period II**
β_0	158.890* (62.748)	-
β_1	0.871** (0.0479)	0.953** (0.0419)
β_2	7.930* (3.880)	-
β_3	-1.978 (3.909)	-
$\beta_0 + \gamma_1$	-	63.744 (52.366)
$\beta_2 + \gamma_2$	-	-2.875 (26.604)
$\beta_3 + \gamma_3$	-	8.599 (22.983)
δ_1 [a]	0.521E-3* (0.213E-3)[b]	-0.463E-2** (0.761E-3)[b]
δ_2 [a]	-	0.459E-2** (0.772E-3)[b]
δ_3 [a]	-1.018E-3** (0.275E-3)[b]	-
δ_4 [a]	-	-

** indicates significance at 1% level and * indicates significance at 5% level, respectively.

a: RSV_{t-1}^{K} and RSV_{t-1}^{US} are not significant in period I whereas RSV_{t}^{US} and RSV_{t-1}^{US} are not significant in period II.

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