Coupling for the Won-Dollar and Yen-Dollar Rates under the Floating Exchange Rate System in Korea: A Fractional Cointegration Approach

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The coupling for the exchange rates for the Won and Yen is regarded as a unique phenomenon since extremely similar movement among different currencies' exchange rates is rarely observed despite the recent world economy integration. This paper considers the exchange rate risk, macroeconomic factors, and the foreign reserves as determinants of the Won-Yen coupling especially for the post-crisis period since the late 90s, and finally compares the three groups of factors to identify the major driving force of the coupling pattern. The empirical findings in the paper suggest that the exchange rate risk for the two currencies is more significantly related to the Won-Yen coupling behavior than the other factors.

Keywords: Won-Yen coupling, Exchange rate risk, Realized volatility, Fractional cointegration

JEL Classification: C22, E41, E31

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I. Introduction

A. Motivation and Background

The exchange rate appears to be one of the key economic variables as most economies are involved in a high degree of openness nowadays. Some small open economies including Korea have become heavily dependent on the international sector, and in particular, their international trades occupy considerable weights in their economies. The importance of the exchange rate is highlighted for trade as well as the financial sector since the exchange rate determines not only the price competitiveness of export goods and but also the asset values of the capital for the economies. Despite such importance of exchange rates, the analysis of the foreign currency market has become more challenging due to enormous amounts of information flowing rapidly into the foreign currency market. As a traditional approach to the exchange rate analysis, Meese and Singleton (1982) suggest that the exchange rate can be fairly described by the random walk process. In the same line with Meese and Singleton (1982), Meese and Rogoff (1983) show that the monetary approach to the exchange rate determination does not outperform the random walk model in depicting the exchange rate movement. While exchange rates move unpredictably in general as discussed in most of the previous studies, the Won-Dollar and Yen-Dollar exchange rates seem to be tied with each other. The so-called Won-Yen coupling provides some information for the Won-Dollar exchange rate movement, and seems to be very pronounced after the Asian crisis. That is why the Won-Dollar exchange rate is thought to be irrelevant to Korean macroeconomic fundamentals.

Such a pronounced but unusual phenomenon, however, seems to receive less attention relative to the strong interdependence between the Korean and Japanese economies, two major economies in Asia. The Won-Yen coupling has been casually accepted with conjecture that the similarity between the two currencies is due to export competition for Korea and Japan. For example, if the Won/Dollar rate falls with more fluctuation relative to the Yen/Dollar rate, that is, the Korean Won currency appreciates relatively to the Yen currency, then the prices of Korean export goods in the U.S. Dollar will rise. Given other factors unchanged, the price competitiveness of Japanese export goods will relatively improve and the Japanese trade surplus will increase since its rival's products in the market become more expensive. An increase in the Japanese trade surplus means a rise in the Dollar supply in the currency market for the Yen and U.S. Dollar, and further the Yen/Dollar exchange rate should drop. As a result, a fall in the Won-Dollar rate leads to a decrease in the Yen-Dollar rate. The competitive relation between Korea and Japan is believed to be one of the main reasons for the Won and Yen coupling. This paper seeks to identify the factors yielding to the Won-Yen coupling beyond the export competition between Korea and Japan.

In general, export rivalry between countries should take a longer time to be established than, say, one month, which is enough time for some hectic change in financial markets. Therefore, if we merely treat the Won-Yen coupling as a consequence of the "long run" export competition between Korea and Japan, then we may fail to notice other possible underlying factors that cause the coupling in the "short run." If some foreign exchange dealer just presumes that the Won-Yen coupling goes on at the degree for the next one year and does not pay attention to the comovement among the two currencies for a year from now, he may lose further information resulting from possible changes in the degree of Won-Yen coupling in tracking the short term exchange rates movement. The current paper focuses on tracing the possibly continuous changes in the degree of Won-Yen coupling rather than judging whether there exists the Won-Yen coupling for quite a long time span. Moreover, this paper intends to identify what factors are influential in determining the degree of Won-Yen coupling. Foreign currency is a financial asset traded in a market institution while heavily depending on the macroeconomic fundamentals for the associated countries. With financial as well as macroeconomic aspects of the Won and Yen currencies, this paper considers some variables relevant to the coupling pattern in order to ascertain the one that is more decisive than the others. The rest of the paper is organized as follows. Section I summarizes the literature related to the Won-Yen coupling. In section II, I introduce econometric techniques and describe the data and preliminary facts for empirical analysis in the paper. At last, section III concludes.

B. Literature Review

Relationship between the exchange rates has been discussed by Baillie and Bollerslev (1989), Baillie and Bollerslev (1994), Sephton and Larsen (1991), and Diebold, Gardeazabal, and Yilmaz (1994). However, those previous studies have obtained some mixed empirical results regarding the existence of some interdependence among the exchange rates. In particular, Baillie and Bollerslev (1989) use seven nominal exchange rates and find supportive evidence for the relationship among the exchange rates considered. Sephton and Larsen (1991) show that the results of Baillie and Bollerslev (1989) are present only for some partition of the whole sample period. Diebold *et al.* (1994) find no evidence for the relationship between the exchange rates by applying the Johansen cointegration test with intercept terms to the same data set as Baillie and Bollerslev (1989). Baillie and Bollerslev (1994) induce the fractional cointegration technique and suggest the possibility for some moderate degree of interdependence among the exchange rates data.

Although the current paper employs the fractional cointegration concept to measure the degree of Won-Yen exchange rate coupling, it extends Baillie and Bollerslev (1994) to consider some underlying factors for the degree of interdependence between the Won and Yen exchange rates in terms of the U.S. Dollar. Baillie and Bollerslev (1994) reveal a form of relationship between the seven exchange rates including major European currencies' and the Japanese Yen, but consider neither the changes in the degree of interdependence among the exchange rates nor economic factors for the relationship between the exchange rates. Nielsen (2004) applies some semi-parametric method to several major currencies exchange rates and find some degree of relationship among the exchange rates. However, he does not consider reasons for any possible change in the degree of interdependence among the exchange rates and just tests for the presence of fractional cointegration. Cho and Lee (2002) is recently recognized for their application of fractional cointegration to the Won and Yen coupling.[1] The previous studies that have used some major European currencies' exchange rates fail to find strong relationships between the exchange rates even though some moderate degrees of relationship among them is observed.

Shim and Jwa (1990) is concerned with the effect of the Yen-Dollar exchange rate on Korean exports and other Korean macroeconomic variables although they do not consider the Won-Yen coupling

[1] The author has not obtained this publication yet. The author myself recognized the paper by Cho and Lee after finishing the current draft.

explicitly. On the other hand, Lee (2000), Lee and Kho (2003), and Chung and Chang (2003) consider the Won and the Yen in different directions. Lee (2000) applies the GARCH model to figure out the relation between the Won-Dollar and Yen-Dollar exchange rates, Lee and Kho (2003) use a VAR model to identify some channels for the relations between the Won-Dollar and Yen-Dollar exchange rates. The channels in Lee and Kho (2003) include "direct channels" such as market expectation and "indirect channels" such as the Korean trade surplus. Chung and Change (2003) consider not only the Won and Yen exchange rate levels but also their volatility measure by GARCH conditional variances. Their main finding is the existence of some asymmetric movement between the Yen appreciation and depreciation periods.

In fact, recent financial researches show rising interests on high frequency time series behavior for relatively short time spans while traditional financial analysis focused on the long time span at lower sample frequency. High frequency time series for many asset price data have become more available due to the increasing use of electrically recorded data system high capacity for data storage. In addition, economic cycles are also shortening due to faster economic operation and improved decision-making process in the economy because of the development in communication and transportation. Foreign exchange markets also receive much interest regarding short run changes in the market. Andersen and Bollerslev (1997) show some empirical evidence for the major economic announcement effect on the exchange rate volatility by using the five-minute Deutch-Mark and Yen exchange rates. The current paper also aims to microscopically observe the Won-Yen coupling phenomenon within the whole sample period considered, rather than judging the whole long time span under the assumption that the degree of Won-Yen coupling is monotonous during the entire period. Further, the current paper plans to find any possible relation between the changes in the Won-Yen coupling and underlying factors suggested below.

Most of the previous studies[2] on the Won-Yen coupling have compared the exchange rate comovement prior and post the Asian crisis. The current paper investigates the Won-Yen coupling issue in a different manner from the previous studies and chooses the post

[2] Most previous studies have been executed by Korean academia and practitioners as mentioned in the text.

Asian crisis period to analyze the Won-Yen coupling under the same exchange rate system with Japan. Similarity between the Won and Yen exchange rate movements should be less under different exchange rate regimes for Korea and Japan than under the common floating exchange rate system. The current paper aims to narrow down the factors influencing the degree of Won-Yen coupling beside exchange rate system between Korea and Japan.

Lee and Kho (2003) use the overall balance of payment for Korea as one of the variables relevant to the Won-Yen coupling, and Chung and Chang (2003) review the Korean interest rate, Korean stock index, and Korean trade surplus and analyze their relevance to the Won-Yen coupling. In the current paper, I consider three types of variables to reflect the Won-Yen coupling. The variables are as follows: 1) the foreign exchange risk; 2) the growth rate differential across Korea and Japan for macroeconomic condition; and 3) growth rate differential across Korea and Japan ~ foreign reserves.

Those three types of variables are motivated by the following reasons. First, I chose to use the foreign exchange rate risk since it represents information for the foreign currency market that integrates all the sorts of change in the foreign currency prices. Risk is central to asset pricing in investment theory, and thus volatility, the most popular price risk measure, is regarded as a key variable in option pricing formula. Secondly, the paper includes some macroeconomic variables such as interest rate differential, real income growth rate differential, money supply growth rate differential, and price change rate differential to investigate whether those macroeconomic variables have significant effect on the Won-Yen coupling. The variables are selected on the basis of the monetary approach to exchange rate determination. Section II explains how the macroeconomic variables are chosen according to the monetary approach. The monetary approach has been empirically investigated by Baillie and Selover (1987) and McDonald and Taylor (1994). The final variable considered for the Won-Yen coupling analysis is the differential between Korean and Japanese foreign reserves. The three types of variables are used as explanatory variables for the regression analysis that is discussed in detail in section II. In addition, the global trend of the U.S. Dollar's value is considered to focus on the coupling between the Won and Yen exchange rates.

In addition, I briefly mention some other possible variables that may be relevant to the coupling pattern, although they are not incorporated into the empirical analysis in the current paper. Such variables include central bank interventions in the foreign currency markets and the degree of export competitiveness of Korea and Japan. Those variables are important candidates as determinants of the Won-Yen coupling although not considered explicitly in the current paper due to the matter of research scope for the paper and unavailability of data. The export competitiveness of Korea and Japan seems to have formed the expectation that the Won and Yen exchange rates move together. But, as mentioned already, changes in the export-competitive relation between Korea and Japan belong to long-run episodes rather than short-time changes such as some financial market episodes. Since the current paper attempts to examine how the Won-Yen coupling has been changing continuously within the entire sample rather than one time change during the whole sample period, we hold on for the export competition issue in empirically investigating the Won-Yen coupling. On the other hand, although consideration for central bank intervention could enrich the current paper's analysis, the data set for the intervention record is not available and thus the intervention issue is not empirically pursued.

II. Empirical Analysis

A. Preliminary Facts

Figure 1 depicts the Won-Dollar exchange rate movement from January 1999 through the first quarter of 2000. According to Figure 1, the Won-Dollar exchange rate volatility seems to be quite high until the end of 1999 while decreasing from the first quarter of 2000. Loosely speaking, the exchange rate was overshooting before 2000 due to the Asian crisis in the second half of 1997. The overshooting displayed by Figure 1 may be consistent with the Won-Dollar exchange rate collapse during the crisis, which could break down the Won-Yen coupling during the crisis as Kim, Wong, and Park (2005) shows.

Figure 2 records the Won-Dollar and Yen-Dollar exchange rates from January 2000 through August 2005 to sketch the coupling between the two exchange rates during that period. It is apparent that the degree of Won-Yen coupling is not monotonous for some subperiods. For instance, the coupling seems to be more pronounced

FIGURE 1
THE WON-DOLLAR EXCHANGE RATE:
THE 1ST QUARTER OF 1999 - THE 4TH QUARTER OF 2000

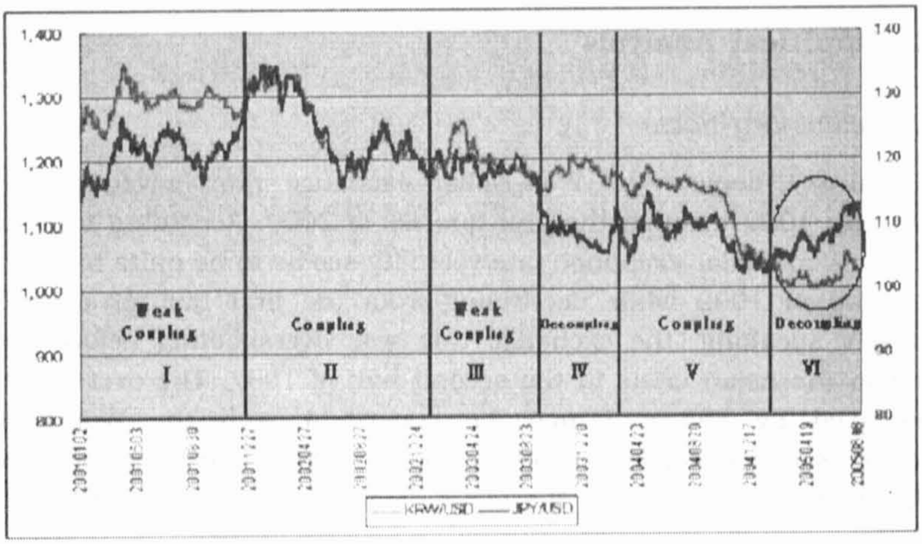

FIGURE 2
WON-YEN COUPLING: 2001.1-2005.8

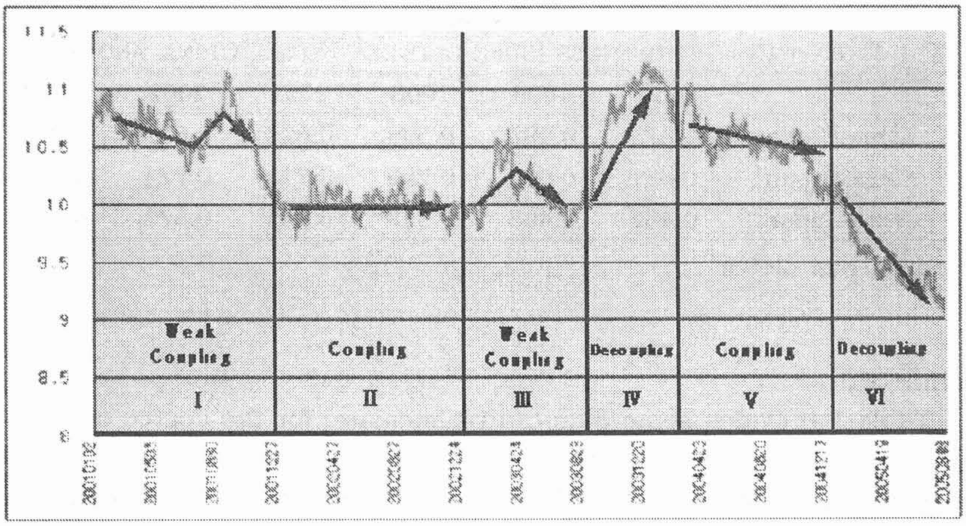

FIGURE 3

THE RATIO OF THE KRW/USD AND JPY/USD: 2001.1.2-2005.8.8

in the subperiod II,[3] than the subperiod IV from September 2003 through the middle of March. 2004. On the other hand, Figure 3 represents the ratio of the Won/Dollar to the Yen/Dollar exchange rates, which is one of the main interests of many Korean export firms since the ratio between the two exchange rates reflects export price competitiveness between Korea and Japan. For the superiod II, the ratio seems to be steady around 10 while falling almost to 9 at the period IV recently.

As mentioned above, from the long-term perspective, the export competition might be a persuasive explanation for the coupling pattern. However, from a relatively short run temporal dimension as displayed in Figure 2 and 3, the Won-Yen coupling does not appear to be constant but rather suggest some possible dynamic changes. The changes in the export competitive power for Korea and Japan is probably not feasible for less than a year or so since their export competitiveness seems to involve some change in the two countries' industrial structures including technological innovation and institutional reforms, which are not likely to change frequently in the

[3] The sample period in Figure 2 and 3 are roughly divided on the basis of eyeballing.

TABLE 1
THE EXPORT COMPETITIVENESS INDEX BETWEEN KOREA, CHINA, AND JAPAN

	1998	1999	2000	2001	2002	2003
Korea-China	0.575	0.593	0.596	0.622	0.639	0.635
Korea-Japan	0.651	0.695	0.729	0.713	0.724	0.730
China-Japan	0.467	0.495	0.517	0.545	0.572	0.595

Source: Kim (2003).

short run.

Table 1 provides some quantitative measure for the degree of export competitiveness among Korea, Japan, and China that Kim (2003) calculated. A large value of the index indicates that the two countries considered involve more export-competition to each other.

I do not deny that the export competitive relation between Korea and Japan *per se* could be the long established reason for the Won-Yen coupling. In fact, the traditional belief regarding the export competition of Korea and Japan seems to make the Won-Yen coupling self-fulfilling, since foreign exchange market participants with the belief of the export competitive relation as a reason for the Won-Yen coupling would predict the Won appreciation in a case of the Yen appreciation with response to. Then, they demand for more of the Won currency, and therefore eventually the actual Won appreciation occurs. However, the export competitiveness index in Table 1 does not seem to be coherent to the degree of Won-Yen coupling as shown in Figure 1. In fact, the Won-Yen coupling is more significant in 2001 than in 2002 and 2003, while the export competition index is slightly less in 2001 than in 2002 and 2003. Then, one could raise some question as to what might be the more relevant reason for the changes in the degree of Won-Yen coupling beyond the export competition between Korea and Japan.

While Figure 2 and 3 sketch a brief picture of changes in the degree of Won-Yen coupling, Table 2 records some quantitative measures for the coupling, which will be explained in more detail later in the paper. Table 2 shows the measures for the currency coupling for six Asian countries only for 2002. A smaller number indicates a more significant coupling for a pair of currencies. Table 2 shows that the Won/Dollar exchange rates move in a manner that is most similar to the Yen/Dollar exchange rates since the

TABLE 2
THE MEASURE FOR THE COUPLING AMONG THE MAJOR EXCHANGE RATES

$y(t)$	$x(t)$	d Coefficient Estimate (2002.01.02-2002.12.31)
Won/Dollar	Yen/Dollar	-0.2233 (-5.088*)
Won Dollar	Euro/Dollar	-0.0713 (-1.855)
Won/Dollar	Baht/Dollar	-0.1274 (-3.470*)
Won/Dollar	Ruphia/Dollar	-0.0359 (-0.888)
Won-Dollar	Canadian-Dollar/Dollar	-0.0435 (-1.161)

Note: (*) represents statistical significance at the five percent confidence interval. The numbers in the parenthesis are the t-values based on the QMLE covariance matrix.

coupling measure for the Won/Dollar and the Yen/Dollar, -0.1274, is the smallest value in the table. Lee and Kho (2003) suggest that capital market liberalization from 1998 through 2000 strengthened the Won-Yen coupling and offer the implication that the capital and financial market liberalization brought about more pronounced coupling between different currencies. However, contrary to their result, the Won-Yen coupling became more significant in 2001 although the capital market liberalization policy slowed after 2000 in terms of the number of the relevant policies and so on.[4]

a) The Realized Volatility of the Won/Dollar and Yen/Dollar Exchange Rates

Figure 4 shows graphs for the series of the realized volatility of the Won/Dollar and Yen/Dollar exchange rates. The lightly colored line displays the realized volatility of the Won/Dollar exchange rate while the dark line for the Yen/Dollar exchange rate. The horizontal axis represents the starting months of each six-month period for which

[4] The list of the capital market liberalization policies before and after the Asian crisis is provided by "The 50*th* anniversary chronicle: Korean Economy" (2000 Bank of Korea).

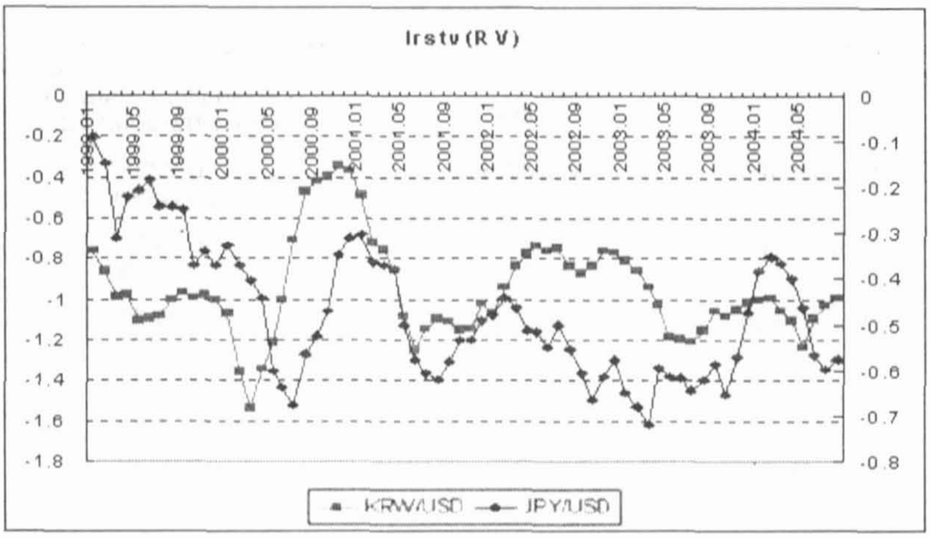

FIGURE 4

THE WON-YEN COUPLING *VS* THE REALIZED VOLATILITY OF THE WON/DOLLAR EXCHANGE RATE AND THE YEN/DOLLAR EXCHANGE RATE: 1999.1-2004.6

the volatility measure is calculated, and the vertical axis represents the volatility measure. The current paper uses realized volatility as the volatility measure following Andersen, Bollerslev, and Diebold (2003). The realized volatility is discussed in more detail later in the paper. One noticeable observation is that the realized volatility of the Won/Dollar exchange rate is larger than the corresponding to the Yen/Dollar exchange rate for most six-month periods.

b) Selected Macroeconomic Variables:

Figure 5 through 8 show graphs for the *M*1 supplies, the CPI indices, interest rates for the two countries' government bond rates, and the industrial production of Korea and Japan. The reason for selecting those macroeconomic variables is discussed later in this paper.

Starting with Figure 5, the vertical axis represents the monthly (seasonally adjusted) *M*1 supplies for Korea and Japan for each month recorded in the horizontal axis. The lightly colored line records the *M*1 supply for Korea in the left vertical axis while the dark line for Japan in the right vertical axis. It is not easy to find any particular pattern in the two currencies' supplies.

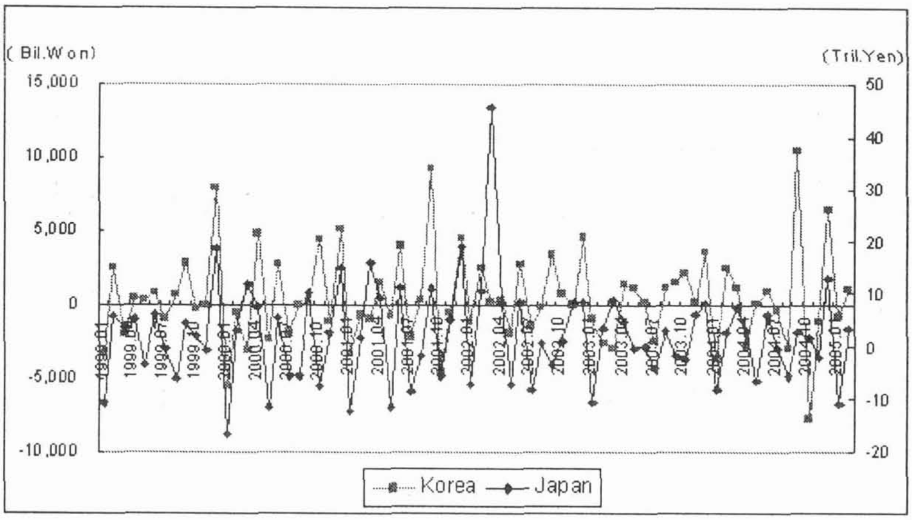

FIGURE 5
THE SEASONALLY ADJUSTED $M1$ SUPPLY FOR KOREA AND JAPAN:
1999.1-2003.5

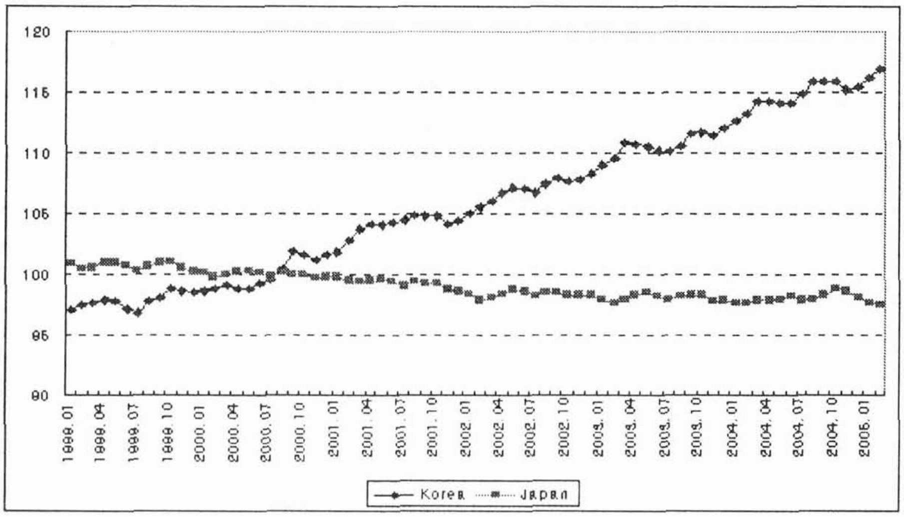

FIGURE 6
THE CONSUMER PRICE INDEX FOR KOREA AND JAPAN:
2001.1-2004.7

Figure 6 exhibits the CPI for Korea and Japan on the base of 1999.

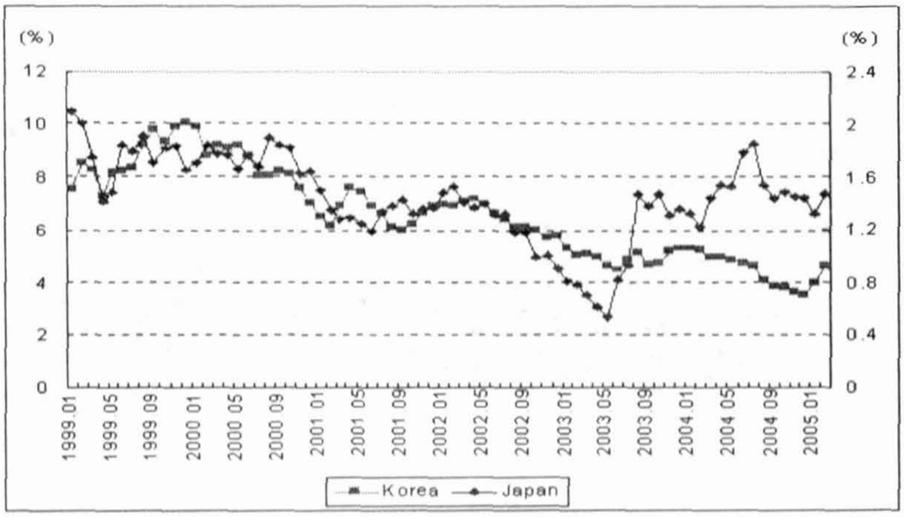

FIGURE 7

THE INTEREST RATE FOR THE KOREAN GOVERNMENT BOND WITH MORE THAN OR EQUAL TO 5 YEARS *VS* THE INTEREST RATE FOR JAPANESE GOVERNMENT BOND WITH 10 YEARS: 1999.1-2005.3

It seems to be that the CPI for Korea represented by the dark line is in a rising trend, while the CPI for Japan represented by the lightly colored line is in a steady phase with a slightly falling trend.

The interest rates for Korean government bond with five-year maturity or longer is represented by the lightly colored line while the corresponding to Japanese government bond represented by the dark line in Figure 7. It is observed that both interest rates exhibit a similar trend from January 1999 to May 2003, while the interest rate for the Japanese government bond turns to a sharply upward trend on May 2003 and since then stays above the Korean government bond rate with quite a big gap.

Figure 8 represents the monthly (seasonally adjusted) industrial production for Korea and Japan with a base of 1999. The lightly colored line indicates the Korean industrial production while the dark line for the industrial production for Japan. The industrial production for Korea is in an upward trend before the first half of 2004 while the corresponding for Japan is in a stable phase.

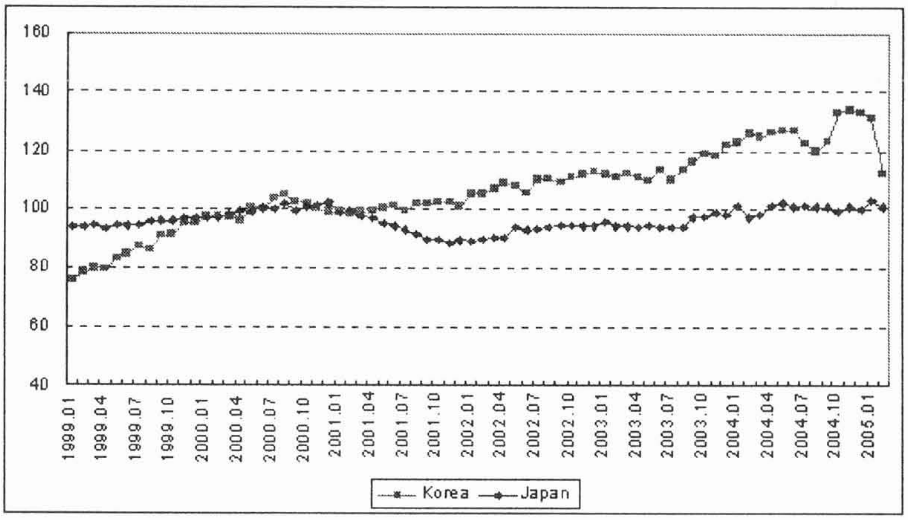

FIGURE 8
THE MONTHLY INDUSTRIAL PRODUCTION: 1999.1-2005.3

c) Foreign Reserves

Figure 9 displays the monthly foreign reserves for Korea and Japan. The lightly colored line represents the monthly change in the foreign reserves for Korea while the dark line for Japan. It is worthwhile to notice a sudden increase in the foreign reserve for Korea in the later part of 2004, which is revealed to be due to the exchange market intervention in 2004 by using the means of derivatives and the NDF market.

Although Korea and Japan officially operate floating exchange rate system, their central banks seem to intervene for foreign exchange stabilization. Consequently, a comparison between the two countries' intervention would be informative in analyzing the Won-Yen coupling. However, unfortunately, the intervention records for Korea are not released for public use while the Bank of Japan announces the intervention data regularly. One possible alternative to gauge the foreign exchange market intervention by the Bank of Korea is to note the difference between foreign reserves and overall payment balance, since foreign reserves represent the quantity of foreign currency at the actual market equilibrium and overall payment balance reflect trade as well as capital transaction, major channel of the supply and demand in the market. The part of the foreign

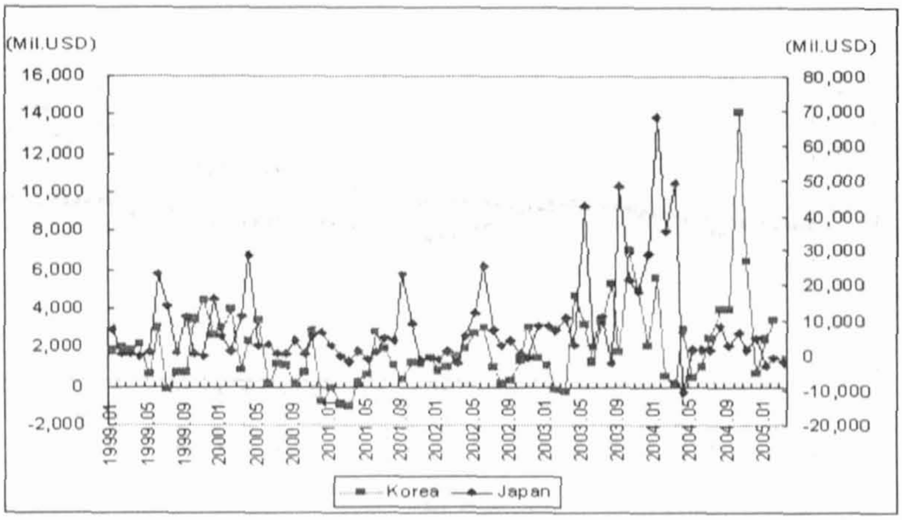

FIGURE 9
THE MONTHLY FOREIGN RESERVE: 1999.1-2005.3

reserves that are unexplainable by the overall payment balance should be attributed to central bank intervention, another channel of the supply and demand in the foreign exchange market. Figure 10 shows the monthly change in the foreign reserves and the overall payment balance for Korea. In particular, a dramatic increase in foreign reserves from August to September 2003 is observed with a sudden fall in the overall payment balance in the same period. The circle in Figure 10 indicates the point at which foreign reserves and overall balance move in opposite directions. It is implied that the foreign intervention by buying U.S. Dollar based assets at that time may be large enough to cover up the balance decrease and even increase the foreign reserves.

As shown in Figure 3, the Won currency exhibits some depreciation relative to the Yen from September 2003, which is consistent with the possible intervention timing indicated by the circle in Figure 10. The ratio of the Won/Dollar to the Yen/Dollar rate is higher than ten, which is maintained for the most of 2002. Another relevant episode to the possible intervention in August 2003 is that Mr. Jin-Pyo Kim, minister of finance and economy at that time, expressed some negative aspects of the Won-Yen coupling. His comment may implicate some necessity for the intervention for the purpose of the

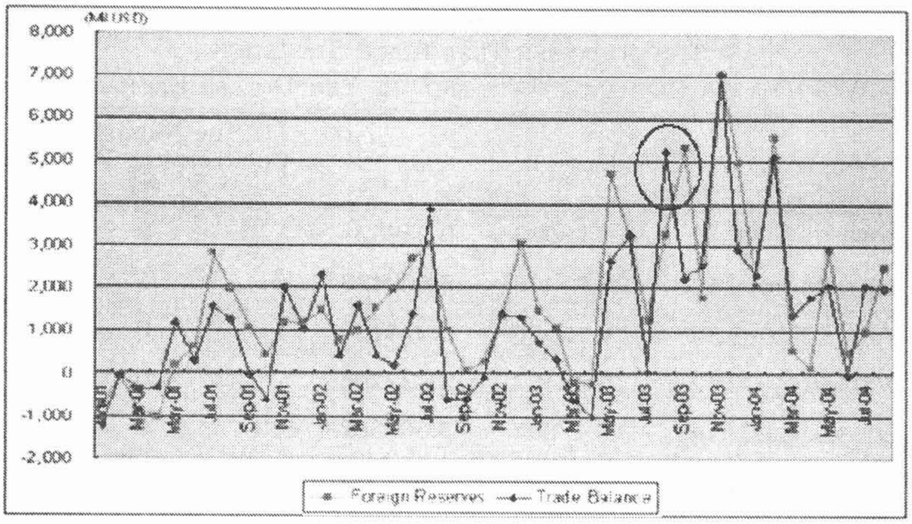

FIGURE 10
THE ESTIMATED FOREIGN MARKET INTERVENTION FOR KOREA: 2000.1-2004.8

Won depreciation relative to the Yen with more weights on the Korean export. As a result, the possible intervention on September 2003 is quite certain and is consistent with the lessened coupling for the Won and Yen exchange rates at that time. Again, the foreign market intervention data for Korea is not accessible and the proxy for the intervention in Figure 10 is very approximate. For those reasons, the intervention issue for the Won-Yen coupling is not pursued further for the rest of the paper.

B. Econometric Model and Data Construction

This section introduces the fractional cointegration method applied to measure the degree of Won-Yen coupling in the current paper. The empirical investigation here starts with statistical properties of the Won/Dollar and the Yen/Dollar exchange rates. I execute the ADF (Augmented Dickey and Fuller) unit root test to confirm the observation for non-stationary exchange rate process as argued by most of the previous studies including Meese and Singleton (1982), Meese and Rogoff (1983), and *etc*. Table 1 and 2 in the appendix show the unit root test results for all the possible six-month periods for the whole sample period from January 1999 to January 2005. According

TABLE 3
THE JOHANSEN TEST TRACE STATISTICS:
THE WON/DOLLAR EXCHANGE RATE AND THE YEN/DOLLAR EXCHANGE RATE

Sample Period	H_0: $r=0$	H_0: $r=1$	The Number of Cointegrating Relations (r)
1991.01-1999.12	12.78076	3.958521	0
2000.01-2000.12	28.67445*	5.600453	1
2001.02-2001.12	10.19525	3.324420	0
2002.01-2002.12	15.48457	2.122256	0
2003.01-2003.12	17.12368	5.368567	0
2004.01-2004.12	13.91544	2.607381	0

Note: * (**) represents rejection of the null hypothesis at the 5% (1%) confidence interval with the null hypothesis being that the number of the cointegrating relations is r. For example, if the null hypothesis for $r=0$ is rejected but the null hypothesis for $r=1$ is not rejected, then the number of cointegration relations should be greater than zero but not greater than one. The critical values for the trace statistics are calculated by Osterwald-Lenum (1992).

to Appendix Table 1 and 2, most of the six-month periods do not reject the null hypothesis for the unit root. The test considers both the case with a linear trend and the case without a time trend for the Won/Dollar and the Yen/Dollar exchange rates. Once we observe that some time series are nonstationary, the existence of the equilibrium relation between those nonstationary time series is tested by using the cointegration test suggested by Johansen (1991), Johansen and Juselius (1990), and Engle and Granger (1987).

This paper adapts the fractional cointegration method to measure the degree of Won-Yen coupling in the current paper, while Baillie and Bollerslev (1994) show the possibility of fractional cointegration relations between seven currencies' exchange rates. Before further discussion, I execute the traditional Johansen cointegration test for the existence of any cointegration relation between the Won/Dollar and Yen/Dollar exchange rates for each year of the whole sample period. According to the cointegration test results in Table 3, there seems to be no cointegration relation except in 2000. Table 3 shows the possibility that the standard cointegration may be misleading. According to the results in Table 3, one may assess that there is no relation between the Won and the Yen exchange rates. The subsequent section shows that there may be some degree of cointegration relation despite the results indicating no cointegration in Table 3.

a) Fractional Cointegration

Fractional cointegration extends the standard cointegration method to embrace the error correction terms with the long memory property. The long memory process is comprehensively surveyed by Baille (1996).

- Fractional cointegration and the Won-Yen coupling

The notion of the Won-Yen coupling in the current paper is different from those of Lee and Kho (2003) and Chung and Change (2003) since the two previous studies consider the coupling by applying the VAR to the Won and Yen exchange returns at the levels. Econometrically, their analysis is not problematic if the standard cointegration relation between the Won/Dollar and Yen/Dollar exchange rates does not exist. If a cointegration relation does exist, however, the VECM (Vector Error Correction Model) should be used for proper analysis as suggested by Engle and Granger (1987). The issue of the current paper is not whether the cointegration relation exists. Rather, the current paper intends to measure the degree of commonness for the stochastic trend shared by the Won/Dollar and the Yen/Dollar exchange rates and to relate the measure for the coupling to the economic factors such as the currency market risk, macroeconomic conditions, and the foreign reserves.

The standard cointegration method provides a framework to test the existence of a long run equilibrium relation and judges the covariance stationarity for the error correction terms on the dichotomy of $I(0)$ such as a white noise process and $I(1)$ processes such as random walk process. The only difference between standard cointegration and fractional cointegration is that the latter allows for some spectrum for the stationarity for the error correction terms from $I(0)$ process to $I(1)$ process. In other words, the standard cointegration may lose some information in terms of the degree of cohesiveness between some time series variables since it considers only $I(0)$ and $I(1)$, two extreme processes. For example, two pairs of time series variables are considered for the standard cointegration test. The fractional cointegration method can sense the differences for the two pairs in terms of the degree of cointegration relation.

The long memory process is defined as follows. First, fractional differencing is defined by Equation (1).

$$(1-L)^d \equiv \{1 - dL + d(d-1)L^2/2! - d(d-1)(d-2)L^3/3! + \cdots\} \tag{1}$$

If some time series variable becomes covariance stationary after being fractionally differenced, the variable is called "the long memory process" which exhibits a slowly decaying autocorrelation. One of the most popular models to represent the long memory process is the Autoregressive Fractionally Integrated Moving Average (ARFIMA) model, and is defined as follows.

$$\varphi(L)(1-L)^d \varepsilon_t = \theta(L)\mu_t \tag{2}$$

where ε_t is a time series variable considered, is a stationary white noise process, and is a polynomial in L, a lag operator. It is assumed that $\varphi(L) = 1 - \varphi_1 L - \varphi_2 L^2 - \varphi_3 L^3 - \cdots - \varphi_p L^p$ and $\theta(L) = 1 - \theta_1 L - \theta_2 L^2 - \theta_3 L^3 - \cdots - \theta_q L^q$. The model expressed by Equation (2) is termed as ARFIMA(p, d, q). The value of d should be less than 0.5 for the covariance stationarity, and should be greater than -0.5 for the invertibility. The AFIMA model reduces to the Autoregressive Integrated Moving Average (ARIMA) with $d=1$, and to the Autoregressive Moving Average (ARMA) with $d=0$, respectively. Therefore, the long memory process is flexible in describing various classes of time series variables with different values of the long memory parameter, d.

The simple fractional cointegration test used in the current paper is a two-step residual based test. The first step is to run a simple OLS regression of some possibly nonstationary time series variable on another nonstationary variable considered for the cointegration relation with its partner variable. The second step is to estimate the long memory parameter for the error correction terms obtained from the first step by using the ARFIMA type models. The long memory parameter estimates are likely to be closer to one for more slowly mean-reverting error terms. On the other hand, the long memory parameter becomes closer to zero for rapidly mean reverting error correction terms. In other words, the long memory parameter estimates for the error correction terms become closer to one if the nonstationary components are even less washed out with each other. However, the long memory parameter estimates get close to zero if nonstationary components are likely to cancel out each other significantly. Such a notion of fractional cointegration implies that the smaller values of the long memory parameter estimates for the error correction terms for the Won/Dollar and Yen/Dollar exchange rates could represent significant coupling between the two exchange rates. In practicing the two-step fractional cointegration test, I apply the ARFIMA(0, d, 0) model to the first-differenced error correction terms for easier calculation routine. As suggested by Diebold and Rudebush (1989), it is difficult to distinguish between the unit root process and the fractional alternatives. For long memory parameter values that are extremely close to one, the MLE may fail to converge to some finite estimates for the long memory parameter. To avoid such a computational problem, the ARFIMA model is applied to the first differenced error correction terms.

There is one econometric issue in executing the fractional cointegration test. As in the case of the standard cointegration test procedure, estimation of the cointegration parameter matters also for the fractional cointegration. Since the OLS estimation of the cointegration parameter may be misleading the subsequent inference when the residuals resulting from the estimation follow $I(1)$ series, I rather assume that the cointegration parameter is known to be one although such an assumption lacks theoretical foundation. Therefore, I apply the ARFIMA(0, d, 0)[5] model to the Won/Dollar rate minus the Yen /Dollar rate at their log level. At the practical level, the correlation coefficient is the most popular measure for the Won-Yen coupling. However, the correlation for nonstationary time series variables with infinite unconditional variance may be statistically controversial. Another motivation for using fractional cointegration as a measure for the Won-Yen coupling is that such a measure could consider common stochastic trends shared by the Won/Dollar and Yen/Dollar exchange rates beyond the exchange return relations.

b) Rolling-over Sampling

The empirical study in the current paper uses the sample period of

[5] I have tried ARFIMA(1, d, 1) and ARFIMA(1, d, 0) models to estimate the long memory parameter, d, and found that the d estimate values do not seem to depend on the p and q orders significantly for this case.

January 1999 to August 2005 at daily sample frequency. The whole sample period is not sufficiently long enough to consider the common stochastic trends for a subperiod within the entire period. In fact, the current paper regards a six-month subsample period as a unit period. Consequently, the number of subsample periods is only twelve, which is not enough for the regression analysis explained later in the paper. The alternative to the short sample period is to roll over and select partially overlapping subsample periods. One could drop the oldest month and add the latest month to update a six-month subsample period. By repeating the routine, more subsample periods could be collected than when choosing non-overlapping subsample periods within the whole sample period. The resulting number of subperiods chosen after the rolling-over sampling is sixty-eight. I estimate the Won-Yen coupling measure and obtain economic variables relevant to the coupling for each of the overlapping subsample periods.

c) The Realized Volatility

The first type of variables considered for the Won-Yen coupling is the foreign exchange market risk. The foreign exchange intrinsically belongs to financial asset and therefore shares some characteristics with equities and derivatives. One of the most important key factors for financial asset management is the price risk, which is represented by asset price volatility usually as a variety of volatility measures are incorporated in option formula suggested by Black and Scholes (1972). Asset price volatility reflects changes for in demand and supply that involve all the information flowing into financial markets. Such an importance for the volatility has initiated enormous researches including the so-called GARCH revolution accomplished by Engle (1982) and Bollerslev (1986). More recently, Andersen and Bollerslev (1998), Andersen, Bollerslev, Diebold, and Labys (2001) suggest the Realized Volatility as a new volatility measure and apply the volatility measure to foreign exchange and stock markets although French, Schwert, and Stambaugh (1987) and Schwert (1989) have previously applied similar concepts to the U.S. stock index since World War II.

The basic idea of the realized volatility is simple in that more accurate price volatility can be calculated by incorporating the price changes for subperiods within the unit period considered for the volatility measurement. A simple example of the realized volatility is as follows. The daily stock return volatility may be obtained by adding up all the squared stock returns every minute. An alternative for the daily volatility is to measure the magnitude of price change between the previous trading day and the current trading day. The statistical merits for using the realized volatility is that it could provide better forecast and exhibit some distribution close to the normal as shown in Andersen, Bollerslev, Diebold, and Labys (2001). Above all, it is simple to calculate unlike the GARCH type conditional variances, which require some maximum likelihood estimation procedures. The realized volatility can be obtained as follows.

$$RV_t = 0.5 \ \ln(\sum_{j=1\,N} r_j / N)$$

where r_j indicates the exchange rate returns for $j\,th$ trading day for the $t\,th$ six-month period, and N represents the number of trading days for the $t\,th$ six-month period. For the Won/Dollar and the Yen/Dollar exchange rates, I calculate the realized volatility for each of the six-month periods selected based on the rolling-over sampling as mentioned above.

d) Macroeconomic Variables Based on the Monetary Approach to Exchange Rate Determination

The monetary approach to exchange rate determination has been developed by Frenkel and Johnson (1976). The model consists of the money market equilibrium, uncovered interest rate parity, and purchasing power parity.

$$m_t - p_t = \varphi y_t - \lambda i_t \tag{3}$$

$$m_t^* - p_t^* = \varphi y_t^* - \lambda i_t^* \tag{4}$$

Equations (3) and (4) represent the money demand function for Korea and the U.S., respectively. m_t expresses the monetary supply, and p_t represents the price level for Korea. Moreover, i_t is the nominal Korean interest rate and y_t is the real income. The (*) indicates the corresponding notations for the U.S.. For simplicity, φ and λ indicate the money demand elasticity with respect to real income and nominal interest rate, respectively. The money demand elasticity with respect to real income and nominal interest rate are assumed to be the same for all the countries.

The uncovered interest parity is expressed as below.

$$i_t - i_t^* = E_t s_{t+1} - s_t \tag{5}$$

s_t represents the logarithmic value of the nominal exchange rate, that is, value of one dollar in terms of the won currency. In addition, the price levels for Korea and the U.S. have the following relation, which is the purchasing power parity.

$$s_t = p_t - p_t^* \tag{6}$$

Following Mark (2000), the "economic fundamental," f_t, is defined as follows.

$$f_t = (m_t - m_t^*) - \varphi(y_t - y_t^*) \tag{7}$$

Substituting Equations (3), (4), and (5) into Equation (6), the nominal exchange rate can be rewritten as below.

$$s_t = f_t + \lambda(E_t s_{t+1} - s_t) \tag{8}$$

First differencing Equation (8) will lead to the following Equation (9).

$$\Delta s_t = \Delta f_t + \lambda \cdot \Delta(E_t s_{t+1} - s_t) \tag{9}$$

By substituting Equations (5) and (7) into Equation (9), we have

$$\begin{aligned} \Delta s_t &= \Delta f_t + \lambda \cdot \Delta(E_t s_{t+1} - s_t) \\ &= \Delta[(m_t - m_t^*) - \varphi(y_t - y_t^*)] + \lambda \cdot \Delta(i_t - i_t^*) \\ &= \Delta m_t - \Delta m_t^* - \varphi(\Delta y_t - \Delta y_t^*) + \lambda \cdot (\Delta i_t - \Delta i_t^*) \end{aligned} \tag{10}$$

The nominal exchange rate for the Yen, that is, the value of the U.S. dollar in terms of the Yen currency can be derived by the same token as the equations above are based on the Won/Dollar exchange rate.

$$\Delta s_t^J = \Delta m_t^J - \Delta m_t^* - \varphi(\Delta y_t^J - \Delta y_t^*) + \lambda \cdot (\Delta i_t^J - \Delta i_t^*) \tag{11}$$

s_t^J represents the nominal exchange rate for the Yen, that is, the value of the U.S. dollar in terms of the Yen currency. Subtracting Equation (11) from Equation (10), we have

$$\Delta s_t - \Delta s_t^J = (\Delta m_t - \Delta m_t^J) - \varphi(\Delta y_t - \Delta y_t^J) + \lambda \cdot (\Delta i_t - \Delta i_t^J) \tag{12}$$

Equation (12) implies that the differential for the nominal exchange rate returns, $\Delta s_t - \Delta s_t^J$ depends on the differential for money supply growth rates, $(\Delta m_t - \Delta m_t^J)$, and the differential for real income growth rates $(\Delta y_t - \Delta y_t^J)$, and the differential for interest rates change $(\Delta i_t - \Delta i_t^J)$. For the empirical analysis in the current paper, I use the industrial production for real income, the $M1$ money supply for the money supply, the interest rate for Korean government bond with greater than or equal to five-year maturity, and Japanese government bond with 10-year maturity.

Although the derived Equation (12) does not explicitly involve, the differential for the CPI across Korea and Japan is considered for the subsequent regression analysis for accounting as many important factors as possible. Equation (12) does not provide a formal derivation but suggests the motivation for the use of the $M1$ supply growth rate differential, the industrial production growth rate differential, and the interest rate change differential as the underlying determinants of the Won-Yen coupling.

For the regression analysis in the later part of the current paper, we manipulate all the macroeconomic variables considered here as follows. First, we take a log for the original data except the interest rate, and then first difference the resulting values. The log differenced macroeconomic variables are often regarded as growth rates for the associated variables. Subsequently, we obtain the absolute difference between those growth rates for Korea and Japan. At last, we calculate the averages for the absolute differences for every six-month period chosen by the rolling-over sampling. The average values are used for the regression analysis at last. The six-month averages for the absolute differences between the two countries' log differenced macroeconomic variables are not equal to the absolute difference between the six-month averages for the log differenced macroeconomic variables for Korea and Japan. The latter may not reflect the monthly change of the growth rate of the macroeconomic variables considered since averaging the growth rates over each six-month period can smooth out monthly changes in the growth rates for each period.

e) Foreign Reserves

I calculate the six-month averages for the absolute differences between the monthly foreign reserves for Korea and Japan to use in the regression analysis later.

C. Empirical Findings

a) The Unit Root Test

As mentioned already, the current paper selects six-month periods by using the rolling-over sampling and considers the relevant variables for those periods for the empirical analysis. One shortcoming of the rolling-over sampling is that adjacent periods are overlapped with each other. For example, the six-month period from January 2000 to June 2000 is overlapped with the period from February 2000 to July 2000 for five months. Therefore, it is possible that the time series variables for the six-month periods considered here may exhibit some temporal persistence, and may suffer a spurious regression problem due to its possible nonstationarity when used for the standard regression methods.

To diagnose any possible unit root property, the ADF unit root test is executed for the time series variables: i) The foreign exchange risk variable measured by the realized volatility of the Won/Dollar and Yen/Dollar exchange rates, ii) the six-month averages for the growth rate differentials between Korea and Japan for the *M*1, the industrial production, the interest rate for the Korean government bond and Japan government bond, and the CPI for Korea and Japan, and iii) the six-month averages for the monthly foreign reserve differentials between the two countries' foreign reserves. The unit root test results for the three types of variables are reported in Table 4.

The test results in Table 4 suggest that the null hypothesis for unit root are not rejected for any significance levels for the case of the Won-Yen coupling measures, the realized volatility of the exchange rates, and the six-month averages for the growth rate differentials between the two countries' foreign reserves. The ADF test rejects the unit root hypotheses for the six-month averages for the CPI growth rate differentials, and the six-month averages for the industrial production growth rate differentials at five percent significance levels, but not at the one percent significance level. In addition, the unit root hypothesis is rejected at the ten percent significance level, but not at the five percent level for the six-month averages for the *M*1 supply

TABLE 4
THE UNIT ROOT TEST

Variable	ADF Test Statistic
The Won-Yen Coupling Measure	-2.617219
The Euro-Yen Coupling Measure	-4.065285**
The RV for the Yen/Dollar Exchange Rate	-3.486246**
The RV for the Won/Dollar Exchange Rate	-3.074874
The CPI Growth Rate Differentials	-3.895889**
The Interest Rate Growth Rate Differentials	-2.569649
The Industrial Production Growth Rate Differentials	-3.544353**
The *M*1 Supply Growth Rate Differentials	-3.199761***
The Foreign Reserve Growth Rate Differentials	-3.064122

Note: *, **, and *** represent rejection of the null hypothesis for unit root at the confidence interval of 1%, 5%, and 10%, respectively. The ADF test procedure here assumes time trend and five lags.

growth rate differentials. Although the unit root test results are mixed depending on the variables considered, it is impossible to reject the unit root hypotheses for all the variables at all the significance levels considered, and quite a strong persistence for the variables seems to exist. Therefore, I first difference all of the variables to get rid of covariance-nonstationarity.

Before proceeding further, I conduct a Johansen cointegration test to detect any cointegration relation between the original variables before being first differenced. If some cointegration relation is confirmed, VECM should be applied to the associated variables so that the error correction term could reflect the long run effect on the dynamic relation among the variables. If no cointegration relation is detected, the standard VAR model could be used for first-differenced variables.

b) Relation between the Coupling and Other Economic Factors

The current paper intends to investigate the relation among the Won-Yen coupling measures and the relevant variables in various dimensions. I plan to figure out how the Won-Yen coupling measure responds to some change in the variables as determinants. There are several possible time series econometric models including VAR and

VECM. Beyond the seminal work by Sims for the VAR method, Sims (1986), Bernanke (1986), and Blanchard and Quah (1989) extend the traditional VAR to incorporate some structures reflecting economic theories, and King, Plosser, Stock, and Watson (1991) modify the standard VECM with some restrictions corresponding to some economic theories.

However, it is not easy to find a well-established economic theory to relate all the variables empirically considered. Also, there is some technically complicated issue such as identification of a structural parameter matrix of the structural VAR or VECM. Due to a lack of evident economic theories for the variables considered for the Won-Yen coupling, I use an OLS model including contemporaneous as well as lagged terms rather than relying on willful assumption for the structural restrictions. If the variables have cointegration relation with each other, then the error correction term will be added to the estimation model.

c) The Foreign Exchange Risk

- Cointegration relation between the Won-Yen coupling measure and the foreign exchange risk

It is possible to conjecture that the global dollar trend measured by the Euro-Yen coupling may have some effect upon the Won-Yen coupling and should be considered to separate out the genuine Won-Yen coupling from the global dollar phase. However, it turns out to be the residual for the preliminary OLS estimation of the Yen/Dollar rate on the Euro/Dollar rate for many six-month periods are very close to the random walk process. In such a case, all sorts of the cointegration procedure would be meaningless due to the spurious estimation of the cointegration parameter. Therefore, under this econometric shortcoming, we do not further consider the measure for the global dollar trend obtained by the same process as the Won-Yen coupling measure.

According to the cointegration results in Table 5, one cointegration relation exists at five percent significance levels while another at the one percent level. Table 6 displays the cointegrating coefficient, and indicates that the coefficient estimate for the Won/Dollar exchange rate volatility is significant at the five percent confidence level and would be negatively signed in a regular regression equation expre-

TABLE 5

COINTEGRATION TEST: THE WON-YEN COUPLING AND THE FOREIGN MARKET RISK

H_0	Trace Statistic
$r=0$	46.99187*
$r=1$	21.56654
$r=2$	8.367910

Note: * (**) represents rejection of the null hypothesis at the 5% (1%) confidence interval with the null hypothesis being that the number of the cointegrating relations is r. For example, if the null hypothesis for $r=0$ is rejected but the null hypothesis for $r=1$ is not rejected, then the number of cointegration relations should be greater than zero but not greater than one. The critical values for the trace statistics are calculated by Osterwald-Lenum (1992).

TABLE 6

THE COEFFICIENT ESTIMATES FOR THE NORMALIZED COINTEGRATION REGRESSION EQUATION. ONE COINTEGRATING RELATION

The Won-Yen Coupling	The RV (Yen/Dollar)	The RV (Won/Dollar)	Trend
1.000000	0.210671	**0.551236****	0.003738
	(0 15365)	(0.07147)	(0.00109)

Note: The numbers in the parenthesis represent standard errors. (*) indicates statistical significance for the associated coefficient estimate at 1% confidence interval.

ssion, and therefore the uncertainty of the Won/Dollar exchange rate could be positively related to the actual degree of coupling, recalling the definition of the Won-Yen coupling measure. The cointegration test results suggest that the level of Won-Yen coupling is tied with the Won/Dollar exchange rate volatility during the contemporaneous six-month period.

However, the cointegration relation may not be informative for more underlying relation between the Won-Yen coupling and the volatility variables since no causality issue is embodied in the cointegration relation. On the other hand, the result in Table 7 implies that the coefficient estimate for the lagged change in the Won/Dollar exchange rate volatility is statistically significant. Since cointegration relation is detected for the Won-Yen coupling and the volatilities of the two currencies' exchange rates as shown in Table 5 and 6, the error

TABLE 7
THE SHOCKS TO THE WON-YEN COUPLING
AND THE SHOCKS TO THE FOREIGN MARKET RISK

Explanatory Variable	The Coefficient Estimates	Standard Error
Error Correction Term	-0.1705	0.0985
Lagged Shock to the Won-Yen Coupling	-0.0547	0.1197
Lagged Shock to the RV for the Yen/Dollar Exchange Rate	0.0020	0.1371
Lagged Shock to the RV for the Won/Dollar Exchange Rate	**-0.2199***	0.0855
Current Shock to the RV for the Yen/Dollar Exchange Rate	-0.0824	0.1373
Current Shock to the RV for the Won/Dollar Exchange Rate	-0.0952	0.0970

Note: (*) indicates statistical significance for the associated coefficient estimates at 5% confidence interval. In addition, the adjusted R-squared is 0.1506 while *Durbin-Watson* statistic is 1.9137.

correction term should be included in the short run dynamic relation and thus a simple OLS model with the error correction term is applied to the Won-Yen coupling and the two exchange rate volatility variables.

According to Table 7, the coefficient for the lagged shock to the Won/Dollar exchange rate volatility are statistically significant at the five percent confidence interval and negatively signed. In particular, the lagged shocks to the Won/Dollar exchange rate volatility are negatively related to the current shocks to the Won/Yen coupling measures, and in turn, positively related to the current changes in the actual degree of Won-Yen coupling following the definition of the Won-Yen coupling in the current paper. In other words, the larger change in the Won/Dollar rate uncertainty for the last six-month period could raise the degree of Won-Yen coupling at the current six-month period by more magnitude. On the other hand, Table 7 indicates that the current shocks to the Yen/Dollar exchange rate volatility do not seem to be influential to the current shocks to the Won-Yen coupling. In sum, the Won-Yen coupling seems to be affected by the lagged shock to the Won/Dollar rate volatility. From the estimation result in Table 7, it can be inferred that when the

TABLE 8

COINTEGRATION TEST. THE WON-YEN COUPLING AND THE GROWTH RATE DIFFERENTIAL ACROSS KOREA AND JAPAN FOR THE SELECTED MACROECONOMIC VARIABLES

H_0	Trace Statistics
$r=0$	73.99733
$r=1$	46.74975
$r=2$	28.49117
$r=3$	12.87520
$r=4$	2.764085

Note: * (**) represents rejection of the null hypothesis at the 5% (1%) confidence interval with the null hypothesis being that the number of the cointegrating relations is r. For example, if the null hypothesis for $r=0$ is rejected but the null hypothesis for $r=1$ is not rejected, then the number of cointegration relations should be greater than zero but not greater than one. The critical values for the trace statistics are calculated by Osterwald-Lenum (1992).

market participants experience more uncertainty for Won/Dollar exchange rate in the past they become more likely to refer to the Yen/Dollar exchange rate in figuring out the current Won/Dollar exchange rate movement. As discussed by Shiller (1999), some recent behavioral finance theories present the possibility that the financial market is subject to some seemingly irrational human behavior such as herd behavior and anchoring behaviors. More volatile Won/Dollar exchange rate in the past may give rise to some necessity for some reference or anchor to follow in the Won and Dollar currencies.

d) Macroeconomic Variable

- Cointegration relation between the Won-Yen coupling measure and macroeconomic variable

Table 8 indicates that the Johansen test does not detect any cointegration relation among the Won-Yen coupling measure and the previously selected macroeconomic variables, six-month average differentials between Korea and Japan for the followings: the $M1$ growth rates, the industrial production growth rates, the government bond interest rate growth rates, and the CPI growth rates. Consequently, the coingrating parameters are not discussed further.

TABLE 9
THE SHOCKS TO THE WON-YEN COUPLING AND THE SHOCKS TO THE GROWTH RATE DIFFERENTIAL ACROSS KOREA AND JAPAN FOR THE SELECTED MACROECONOMIC VARIABLES

Explanatory Variable	The Coefficient Estimates	Standard Error
Lagged Shock to the Won-Yen Coupling	0.1982	0.1201
Lagged Shock to the CPI Growth Rate Differential between Korea and Japan	1.1330	7.3565
Lagged Shock to the Interest Rate Change Differential between Korea and Japan	-0.4798	0.3369
Lagged Shock to the Industrial Production Growth Rate Differential between Korea and Japan	-1.0595	2.1579
Lagged Shock to the *M*1 Growth Rate Differential between Korea and Japan	1.0848	1.1016
Current Shock to the CPI Growth Rate Differential between Korea and Japan	-13.0427	6.8656
Current Shock to the Interest Rate Change Differential between Korea and Japan	0.5084	0.3469
Current Shock to the Industrial Production Growth Rate Differential between Korea and Japan	0.7237	2.2739
Current Shock to the *M*1 Growth Rate Differential between Korea and Japan	1.1099	1.1118

Note: Adjusted R^2 is 0.0623, and *Durbin-Watson* is 1.9976.

- Short run dynamics

Table 9 reports the estimation results for changes in the Won-Yen coupling and the selected macroeconomic variables. The error correction term is not included in the regression model since the Johansen test result in Table 8 does not find any cointegration relation for the Won-Yen coupling measure and those selected macroeconomic variables. Somewhat surprisingly, none of the explanatory variables in Table 9 exhibit statistical significance. Also, the adjusted R square is even lower than the one for the regression with the volatility variables as shown in Table 7.

e) Foreign Reserve

TABLE 10
COINTEGRATION TEST: THE WON-YEN COUPLING AND THE FOREIGN RESERVE DIFFERENTIALS ACROSS KOREA AND JAPAN

H_0	Trace
$r=0$	22.7899
$r=1$	5.4075

Note: * (**) represents rejection of the null hypothesis at the 5% (1%) confidence interval with the null hypothesis being that the number of the cointegrating relations is r. For example, if the null hypothesis for $r=0$ is rejected but the null hypothesis for $r=1$ is not rejected, then the number of cointegration relations should be greater than zero but not greater than one. The critical values for the trace statistics are calculated by Osterwald-Lenum (1992).

- Cointegration relation between the Won-Yen coupling measure and the foreign reserves

As the macroeconomic variable case, Table 10 fails to find any evidence for the cointegration relation between the Won-Yen coupling and the six-month average foreign reserve differential between Korea and Japan.

- Short run dynamics

Since no cointegration relation is detected for the Won-Yen coupling measure, no error correction term is considered to investigate some short run dynamic relations among the shocks to the variables. The lagged shock to the foreign reserve growth rate differential across Korea and Japan are statistically significant and positive. The positive sign for the coefficients for the current shock to the foreign reserve growth rate differential implies that the larger foreign reserve gap in the previous six-month period across Korea and Japan could be related to the larger shock to the Won-Yen coupling measure, and consequently the smaller shock to the actual degree of the Won-Yen coupling. The result in Table 11 is sensible since it implies that the more different foreign reserve dynamics across Korea and Japan could lead to less similarity between the Won/Dollar and Yen/Dollar exchange rates.

TABLE 11
THE SHOCKS TO THE WON-YEN COUPLING AND THE SHOCKS TO THE FOREIGN RESERVE DIFFERENTIALS ACROSS KOREA AND JAPAN

Explanatory Variable	The Coefficient Estimates	Standard Error
Lagged Shock to the Won-Yen Coupling	0.1312	0.1119
Lagged Shock to the Growth Rate Differential across Korean and Japanese Foreign Reserves	**3.5325***	1.5251
Current Shock to the Growth Rate Differential across Korean and Japanese Foreign Reserves	0.4745	1.5258

Note: (*) indicates statistical significance for the associated coefficient estimates at 5% confidence interval. The adjusted R^2 is 0.0567, and *Durbin-Watson* is 2.0220.

f) Comparing the Foreign Exchange Market Risk, the Selected Macroeconomic Variables, and the Foreign Reserves

The current paper considers three classes of economic variables: The foreign market risk, the macroeconomic variables based on the monetary approach, and the foreign reserves to study the relation between those variables and the Won-Yen coupling. In the current subsection, I compare the performance of the three types of variables. The most popular alternative to this is to include all three types of variables in an integrated regression set up and to compare the statistical significance of the coefficients of those variables. However, the number of possible determinants of the Won-Yen coupling would be too large relative to the sample size available for the current empirical analysis. In fact, we found statistically significant coefficient estimates only for the lagged change in the Won/Dollar rate volatility and the lagged change in the foreign reserve growth rate gap for the two countries. For the selected macroeconomic variables, there seems to be no relation between the changes for the variables considered. In particular, there is a cointegration relation between the Won-Yen coupling measure and the volatility variables while no cointegration relation is detected with respect to the other two groups of variables, macroeconomic variables and foreign reserve. Also, the adjusted R^2 is 15 percent for the regression equation with the Won-Yen coupling measure as a dependent variable and the foreign currency market risk as regressors. The adjusted R^2 for the regression equation with the growth rate differential between Korea and Japan for the selected macroeconomic variables as its regressors is equal to only six percent while the corresponding one with the foreign reserve differential between Korea and Japan is five percent. The empirical findings imply that the foreign exchange market risk is more crucial in explaining the degree of Won-Yen coupling than the selected macroeconomic variables. This statement is worthwhile to note since those macroeconomic variables are based on the established exchange rate theory and there seems to be no theoretical foundation for the relation between exchange rate risk and exchange rate comovement for the case of the Won and the Yen.

III. Conclusion

The Won-Yen coupling has been observed more frequently since the Asian crisis upon which Korea has adapted the free floating market system for the Won currency. Besides the market based exchange rate system, the Korean economy has faced rapid capital and financial market liberalization. Most of the previous studies on the Won-Yen coupling assess that a big tide of capital liberalization is responsible for the pronounced Won-Yen coupling in the post-crisis period. The current paper motivates the possibility that the Won-Yen coupling is characterized by some dynamics rather than a monotone at some steady extent. As international capital flow over the world rapidly due to transportation and communication development, the cycles of economic changes are shortening. Therefore, if one ignores the possible dynamics for the exchange rate movements within some period, probably he or she may lose some insightful information in figuring out the exchange rate phase. The current paper scans the whole sample period after the Asian crisis in order to study richer dynamics and underlying determinants of the Won-Yen coupling phenomenon. I apply the fractional cointegration method to gauge the continuously changing degree of Won-Yen coupling. With the Won-Yen coupling measured by the fractional cointegration, three groups of possible factors for the Won-Yen coupling are considered for the empirical investigation.

The main empirical findings are summarized as follows. First, starting with the foreign exchange rate risk, the Yen/Dollar exchange rate volatility seems to be positively tied with the Won-Yen coupling at their levels while the lagged shock to the Won/Dollar exchange rate volatility are positively related to the actual degree of Won-Yen coupling. Secondly, the current paper considers macroeconomic variables such as the interest rate, the real income, the money supply, and the price levels based on the monetary approach to exchange rate determination to explain the dynamics for the Won-Yen coupling. Our result implies that the changes in the selected macroeconomic variables may not be significantly relevant to the Won-Yen coupling dynamics. Finally, the lagged change in the foreign reserve gap between Korea and Japan seems to be negatively related to the Won-Yen coupling change.

The Korean economy is a typical open economy, and now faces an increase in trading volume and international capital transactions accelerated since the Asian crisis. Therefore, it is needless to say that the exchange rate is one of the key economic variables in policy making and financial risk management. The current paper proposes a deeper analysis of the Won-Yen coupling, and obtains some lesson that the currency market may be more subject to the exchange rate risk rather than some seemingly relevant macroeconomic fundamentals for shorter time dimension. Although the relation among some major exchange rates is an important issue as the world economy becomes integrated, traditional macroeconomic theories do not yet seem to be perfectly successful in guiding one to seek for underlying factors for the exchange rate coupling. The current paper aims to call attention to the issue at least empirically while hoping for more advanced theory embracing the exchange rate coupling phenomenon in the future.

However, this paper remains with some limits for the scope and methodology. The time span for the data used in the current paper is not long, and thus partially overlapping subperiods are used to microscopically analyze the Won-Yen coupling phenomenon. If higher sample frequency data for the sample period and larger sample are available, then non-overlapping subperiods could be used for considering the Won-Yen coupling within each of the subperiods. Secondly, the fractional cointegration used in the current paper is quite primitive in that the current paper only focuses on the size of the long memory parameter estimates for the error correction terms in order to use it as a measure for the Won-Yen coupling. In fact, however, it is not easy to clearly distinguish some persistent process between the long memory process and the unit root process since there are some further econometrically technical issues regarding the fractional cointegration test procedure for the presence of the long memory property against the unit root process as surveyed by Nielsen (2004). Despite all the shortcomings of the paper, it is worthwhile to pursue further issues on the relation among major exchange rates. In particular, as the Chinese Yuan currency is recently emerging in the world economy, it is tempting to ask whether the Yuan and the Won are coupled or the existing Won-Yen coupling would be obsolete when China adapts a more advanced market based exchange rate system. More serious consideration of the current currency coupling phenomenon should precede the answer to the question in the future. Further consideration of the issue is left for future studies.

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APPENDIX TABLE 1

ADF TEST (WON/DOLLAR EXCHANGE RATE)

Periods		ADF Test *t*-value	
From	To	Case without a Time Trend	Case with a Linear Trend
1999.01.04	1999.06.30	-1.3116	-1.4494
1999.02.01	1999.07.30	-1.9865	-2.8399
1999.03.02	1999.08.31	-2.2580	-2.0826
1999.04.01	1999.09.30	-2.1987	-2.0738
1999.05.03	1999.10.29	-1.9189	-2.5660
1999.06.01	1999.11.30	-1.3629	-0.9589
1999.07.01	1999.12.30	-0.9927	-2.3258
1999.08.02	2000.01.31	-0.0742	-1.8519
1999.09.01	2000.02.29	-0.8077	-1.8318
1999.10.01	2000.03.31	-1.2525	-1.6099
1999.11.01	2000.04.29	-2.3601	-2.5191
1999.12.01	2000.05.31	-2.2470	-2.1028
2000.01.04	2000.06.30	-2.7240***	-2.9395
2000.02.01	2000.07.31	-2.9286**	-2.9116
2000.03.02	2000.08.31	-3.0164**	-2.9970
2000.04.03	2000.09.29	-4.2993*	-4.2703*
2000.05.02	2000.10.31	-3.0665**	-3.1300***
2000.06.01	2000.11.30	0.8394	-0.2357
2000.07.03	2000.12.29	1.1547	-0.7611
2000.08.01	2001.01.31	0.0677	-2.1353
2000.09.01	2001.02.28	-1.0651	-1.7354
2000.10.02	2001.03.30	-1.0484	-2.0341
2000.11.01	2001.04.30	-1.8032	-2.2803
2000.12.01	2001.05.31	-2.0767	-1.9576
2001.01.02	2001.06.29	-1.5900	-1.6651
2001.02.01	2001.07.31	-1.8276	-1.7343
2001.03.02	2001.08.31	-2.2756	-2.8990
2001.04.02	2001.09.29	-3.5746*	-2.6484
2001.05.02	2001.10.31	-2.0182	-2.0174
2001.06.01	2001.11.30	-1.7572	-1.9704
2001.07.02	2001.12.31	-1.6115	-1.2280
2001.08.01	2002.01.31	-1.5339	-1.8001
2001.09.03	2002.02.28	-1.1475	-1.5637
2001.10.04	2002.03.29	-1.0065	-2.2643

(Table Continued)

APPENDIX TABLE 1

ADF TEST (WON/DOLLAR EXCHANGE RATE)

Periods		ADF Test *t*-value	
From	To	Case without a Time Trend	Case with a Linear Trend
2001.11.01	2002.04.30	-1.4100	-0.9574
2001.12.03	2002.05.31	-0.1861	-0.3179
2002.01.02	2002.06.29	1.1480	-1.0931
2002.02.01	2002.07.31	-0.4223	-2.1503
2002.03.04	2002.08.30	-0.8105	-1.0221
2002.04.01	2002.09.30	-2.3437	0.0066
2002.05.02	2002.10.31	-2.2508	-1.9382
2002.06.03	2002.11.29	-1.6970	-2.0252
2002.07.02	2002.12.31	-1.6038	-1.5170
2002.08.01	2003.01.30	-0.8030	-1.1481
2002.09.02	2003.02.28	-1.5941	-3.1751***
2002.10.01	2003.03.31	-1.6972	-1.0935
2002.11.01	2003.04.30	-1.8280	-2.0711
2002.12.02	2003.05.30	-2.0394	-2.4879
2003.01.02	2003.06.30	-1.9333	-1.8531
2003.02.03	2003.07.31	-1.9435	-2.8756
2003.03.03	2003.08.29	-1.4394	-3.3802***
2003.04.01	2003.09.30	-2.5532	-4.5450
2003.05.02	2003.10.31	-1.7842	-2.4943
2003.06.02	2003.11.28	-2.0257	-1.3553
2003.07.01	2003.12.31	-1.7989	-2.0997
2003.08.01	2004.01.30	-2.0307	-2.5030
2003.09.01	2004.02.28	-2.1654	-2.1948
2003.10.01	2004.03.31	-2.6008***	-3.1496***
2003.11.03	2004.04.30	-1.7356	-3.1175***
2003.12.01	2004.05.31	-1.9505	-2.1001
2004.01.02	2004.06.30	-2.0551	-2.1379
2004.02.02	2004.07.30	-2.2103	-2.1599
2004.03.02	2004.08.31	-2.3569	-2.3321
2004.04.01	2004.09.30	-2.0513	-2.7094
2004.05.03	2004.10.29	-0.9650	-2.2050
2004.06.01	2004.11.30	3.4597	2.0944
2004.07.01	2004.12.31	0.2270	-1.8989
2004.08.02	2004.01.31	-0.1907	-1.9518

Note: *, **, and *** represent the rejection of the null hypothesis for unit root at the confidence interval of 1%, 5%, and 10%, respectively.

APPENDIX TABLE 2
ADF TEST (YEN/DOLLAR EXCHANGE RATE)

Periods		ADF Test t-value	
From	To	Case without a Time Trend	Case with a Linear Trend
1999.01.04	1999.06.30	-2.67528***	-2.94729
1999.02.01	1999.07.30	-3.53059*	-2.96415
1999.03.02	1999.08.31	-0.54557	-1.13767
1999.04.01	1999.09.30	0.01100	-1.42875
1999.05.03	1999.10.29	0.02573	-2.80211
1999.06.01	1999.11.30	-0.57643	-1.92716
1999.07.01	1999.12.30	-2.32442	-1.86797
1999.08.02	2000.01.31	-2.61310***	-1.25791
1999.09.01	2000.02.29	-1.98651	-1.99152
1999.10.01	2000.03.31	-1.91637	-2.34377
1999.11.01	2000.04.29	-1.69164	-2.31528
1999.12.01	2000.05.31	-2.18013	-2.11422
2000.01.04	2000.06.30	-2.4121	-2.4378
2000.02.01	2000.07.31	-2.2890	-2.0607
2000.03.02	2000.08.31	-2.2545	-2.6024
2000.04.03	2000.09.29	-2.1357	-2.1279
2000.05.02	2000.10.31	-2.0663	-2.2764
2000.06.01	2000.11.30	-1.2388	-1.7986
2000.07.03	2000.12.29	0.5805	-0.6258
2000.08.01	2001.01.31	-0.1285	-2.3062
2000.09.01	2001.02.28	-1.1317	-1.6974
2000.10.02	2001.03.30	0.2630	-2.6799
2000.11.01	2001.04.30	-1.3207	-2.3805
2000.12.01	2001.05.31	-2.1009	-1.3471
2001.01.02	2001.06.29	-1.4473	-1.9202
2001.02.01	2001.07.31	-1.9669	-2.0463
2001.03.02	2001.08.31	-2.2996	-2.1503
2001.04.02	2001.09.29	-1.9995	-2.1833
2001.05.02	2001.10.31	-1.9099	-2.1351
2001.06.01	2001.11.30	-1.8738	-1.9159
2001.07.02	2001.12.31	-0.3070	-0.6994
2001.08.01	2002.01.31	-0.0913	-2.8888
2001.09.03	2002.02.28	-0.2047	-2.8372
2001.10.04	2002.03.29	-1.4135	-1.6585

(Table Continued)

APPENDIX TABLE 2
ADF TEST (YEN/DOLLAR EXCHANGE RATE)

Periods		ADF Test *t*-value	
From	To	Case without a Time Trend	Case with a Linear Trend
2001.11.01	2002.04.30	-2.2016	-1.0413
2001.12.03	2002.05.31	-1.2582	-1.9275
2002.01.02	2002.06.29	0.2178	-1.9833
2002.02.01	2002.07.31	-1.0642	-2.6965
2002.03.04	2002.08.30	-0.5518	-2.9193
2002.04.01	2002.09.30	-1.9153	-0.7431
2002.05.02	2002.10.31	-2.4247	-2.0606
2002.06.03	2002.11.29	-2.3279	-2.8203
2002.07.02	2002.12.31	-1.9834	-1.8557
2002.08.01	2003.01.30	-1.6932	-1.6623
2002.09.02	2003.02.28	-2.0362	-3.4708**
2002.10.01	2003.03.31	-2.1198	-2.8973
2002.11.01	2003.04.30	-2.2496	-2.5451
2002.12.02	2003.05.30	-3.2869**	-3.3230***
2003.01.02	2003.06.30	-3.2810**	-3.2823***
2003.02.03	2003.07.31	-3.2162**	-3.0812
2003.03.03	2003.08.29	-3.2049**	-3.2656***
2003.04.01	2003.09.30	-0.1178	-0.7281
2003.05.02	2003.10.31	0.5064	-1.1121
2003.06.02	2003.11.28	-0.2370	-1.8445
2003.07.01	2003.12.31	-0.5456	-1.8192
2003.08.01	2004.01.30	-1.8277	-1.5002
2003.09.01	2004.02.28	-3.5713*	-2.2911
2003.10.01	2004.03.31	-2.1131	-2.3406
2003.11.03	2004.04.30	-2.6201***	-2.4681
2003.12.01	2004.05.31	-2.2342	-2.5789
2004.01.02	2004.06.30	-2.1475	-2.3654
2004.02.02	2004.07.30	-2.2467	-2.4668
2004.03.02	2004.08.31	-2.3197	-2.6222
2004.04.01	2004.09.30	-3.0823**	-3.0019
2004.05.03	2004.10.29	-1.9953	-2.2026
2004.06.01	2004.11.30	0.7066	-0.2281
2004.07.01	2004.12.31	-0.2535	-2.1979
2004.08.02	2004.01.31	-0.9798	-1.8549

Note: *, **, and *** represent the rejection of the null hypothesis for unit root at the confidence interval of 1%, 5%, and 10%, respectively.

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