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# Measuring the Degree of Currency Misalignment Using Offshore Forward Exchange Rates: The Case of the Korean Financial Crisis

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## Abstract

This paper proposes a new method of measuring the degree of currency misalignment through the use of offshore forward exchange rates. Using default risk adjusted no-arbitrage conditions for forward exchange contracts, we calculate the spot exchange rates and the domestic interest rates that are implied from the observed forward exchange rates. The difference between the implied and the observed spot exchange rates is our measure of currency misalignment. Our methodology is based on the presumption that, during a currency crisis, offshore forward exchange rates reflect market fundamentals more closely than onshore spot and forward exchange rates. The latter are usually tightly regulated and heavily affected by government intervention during a non-normal event such as a financial crisis. We apply the method to the Korean financial crisis in 1997 and discuss its implication for evaluating the IMF adjustment program and explaining foreign capital flows.

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## I. Introduction

This paper proposes a new method of measuring the degree of currency misalignment through the use of offshore forward exchange rates; it then applies this method to the 1997 Korean financial crisis. Unlike the Latin American debt crises of the 1980s, which were largely the result of mismanaged monetary and fiscal policy, Korea's crisis originated in the country's background structural problems including excessive debt financing and weak regulation of financial intermediaries. (Corsetti, Presenti and Roubini (1998), Fischer (1998), Krugman (1998), Park and Rhee (1998))

In particular, many researchers believe that the Korean won was not significantly overvalued in the months before the Korean financial crisis. (Chinn (1998), Goldstein (1998), Goldfajn and Baig (1998), Lane, et al. (1999), and Lee (1997))[1] However, this judgement has not been well received outside academic circles. In the two-month period from October to December in 1997, the Korean won depreciated by 53 percent against the US dollar. Such a drastic drop of currency values has led many to believe that the Korean won was either significantly overvalued on the eve of the crisis or became irrationally undervalued immediately after the crisis began. In either case many non-academics do not easily accept the academic verdict that the foreign exchange market provided accurate price signals during the crisis period.

This sharp disagreement is not surprising given that there is no consensus on how to measure the degree of currency misalignment even among economists. The economic literature suggests three distinct approaches to measuring currency misalignment, summarized in Chinn (1988), Edward (1994), and Williamson (1994). The first approach is based on a simple no-arbitrage condition such as purchasing power parity. The second is based on a formal macroeconomic model of exchange rate determination. The third is based on the concept of long-run solvency and current account sustainability. Even leaving aside the conceptual concerns in selecting an accurate definition of currency overvaluation, however, there exists a practical problem in implementing any of these estimation methods: during a non-normal event such as a financial crisis, the results are highly dependent on the assumptions and models used.[2] (Bayoumi et al (1994))

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[1] In a very thorough empirical study, Chinn (1998) concludes that the Korean won was undervalued, not overvalued, prior to the crisis while the currencies of the other crisis-hit Asian countries were slightly overvalued.

[2] For example, we calculated the degree of overvaluation of the Korean won by varying the base periods in which we apply purchasing power parity. The degrees of overvaluation of the Korean won against the U.S. dollar at the end of 1997 are estimated to be 10 percent, -12.9 percent, and 3.7 percent, respectively, depending on which base year is chosen. Three different base periods are compared during which the current

To address this issue, we introduce a new method of measuring currency misalignment, particularly during and immediately preceding a financial crisis. Using the observed offshore forward exchange rates, we calculate the spot exchange rate implied from the covered interest parity. The difference between the implied and the observed spot exchange rates is then our new measure of currency misalignment: it measures the deviation of the observed spot exchange rate from the level that the participants in the offshore forward exchange market expect to prevail.[3]

Our method treats the forward and the spot exchange rate differently in a no-arbitrage condition, since we believe that during the Korean financial crisis the former reflected market sentiment more closely than the latter. The presumption is based on our use of non-deriverable forwards (NDFs) which are traded in the *offshore* and not the domestic market. During the currency crisis, the Bank of Korea intervened in the domestic spot and forward exchange markets in order to uphold the value of the won. However, as we will explain in section II, NDFs for the Korean won were traded in Hong Kong and Singapore without the direct regulation and intervention of the Korean government. By that account, we believe that the forward exchange rate in the NDF market could reflect market sentiment more closely than the domestic rate.

One problem with our approach is that the covered interest parity in general does not hold during a financial crisis if foreign investors fear that the local government may impose regulations that prevent the free movement of foreign funds or if the default probability of borrowers increases significantly.[4] To take care of this problem, we adjust the covered interest parity by explicitly considering the political or the default risk. These risks are estimated using the yield spreads between a dollar-denominated Korean government bond and the U.S. Treasury bond of a similar maturity, which is a generally accepted measure of sovereign risk premium.

In addition, our method calculates not only the implied spot exchange rates but also the implied interest rates on won-denominated bonds by solving no-arbitrage conditions for forward contracts

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account of Korea was nearly balanced: the period from the first half of 1985 to the second half of 1986, the period from the second half of 1989 to the first half of 1990, and the year 1993. The results are also sensitive to other alternative assumptions such as the choice of price indices, including or excluding time trends in measuring equilibrium exchange rates, etc.

[3] It is important to understand that the Korean won is not an international currency and there is no offshore spot exchange market for the Korean won. Therfore, even if foreign investors believe that the Korean won is overvalued, there is a limit that they can exploit the arbitrage opportunity by selling won. As such, the implied spot exchange rates in our method can deviate from the observed spot exchange rates. However, when the Korean won is undervalued, it is true that arbitrage transaction can be made by buying won at the onshore exchange market.

[4] Aliber (1973) discusses the role of political and country risk in the forward exchange market. Durbin and Ng (1999) studies the effect of country risk in emerging market bond pricing.

with different maturities simultaneously. The difference between the implied and the observed domestic interest rates has some interesting implications for evaluating the high interest rate policy of the IMF adjustment program in Korea.

The empirical results suggest that the Korean won was overvalued against the U.S. dollar by 4 to 11 percent on the eve of the country's crisis in November 1997. These estimates are significantly larger than those in previous studies. (Chinn (1998), Goldstein (1998), Goldfajn and Baig (1998), and Lee (1997)) Our results also show that the sharp depreciation of the won against the dollar in December 1997 made the won undervalued in the beginning of 1998. However, contrary to popular belief, the degree of under-valuation was not large enough to resume capital inflows into Korea. After then, the Korean won became significantly overvalued again in the middle of 1998, when the Korean government started to aggressively ease its monetary policy stance and a new round of financial crises in emerging markets developed in Russia and Brazil. Only since the end of 1998 does our method find no significant misalignment.

The paper is organized as follows. Section II explains our methodology and the institutional structure of the NDF market for the Korean won. In section III, we report the estimated default probability and the degree of currency misalignment during the period bordering the Korean crisis in 1997. In addition, the domestic interest rates implied from the covered interest parity are compared with the observed rates. Section IV relates our findings to the patterns of foreign capital flows during the Korean financial crisis, and section V concludes.

## II. Methodology

If capital is perfectly mobile across borders, the covered interest parity should hold between spot and forward exchange rates.[5] By treating the observed forward exchange rate as exogenous, we calculate the implied spot exchange rate that satisfies the covered interest parity. The ratio of the implied spot exchange rate over the observed spot rate is our measure of currency misalignment.

Needless to say, spot exchange rates, forward exchange rates and interest rates are all endogenous variables. Therefore, it generally does not make sense to treat one variable as exogenous and the other as endogenous in the covered interest parity. In practice, however, it is easy to find such cases. For example, currency traders often quote the forward exchange rates by looking at current interest rates and spot exchange rates and using the covered interest parity formula. In

contrast to their approach, our method switches the role of the spot and the forward exchange rates since we believe that the latter reflected market sentiment better than the former immediately before and during the Korean crisis in 1997. This presumption depends crucially on our use of non-deliverable forwards (NDFs) which are traded in the offshore foreign exchange market.

NDFs are derivatives that allow participants to hedge exposure to currencies in which a natural forward market does not exist or is not accessible because of controls imposed by local authorities. These derivatives are called non-deliverable since NDF settlements at maturity are made in US dollars at the prevailing exchange rate and no local currency changes hands. Currently, two of the biggest Asian NDF markets are for the Korean won and the New Taiwan Dollar, which are mostly traded in Hong Kong and Singapore. In 1997, the daily NDF transactions were close to US$250 million for the Korean won and US$150 million for the New Taiwan Dollar, respectively. Even though maturity dates are still fairly short, usually at two years or less, the market size has steadily grown together with the growth of trade volume and capital flows within the region.

During the currency crisis, the Bank of Korea actively intervened in the domestic spot and forward exchange markets and tightly regulated capital transactions to uphold the value of the won. However, since the NDF market for the Korean won was not under the direct regulation and intervention of the Korean government, its forward exchange rate could have reflected market sentiment more closely than the spot and the forward rates in the domestic market. Therefore, we would like to interpret the spot exchange rates implied from the NDF forward exchange rates as the equilibrium rates that would have prevailed had the government not intervened in the domestic market.

We can see supporting evidence in Figure 1, which depicts the movement of the one-month forward exchange rates in the domestic forward market and the NDF market together with the spot exchange rate. During the first half of 1997, the forward exchange rates in both markets closely followed the spot exchange rate. Starting from July 1997 the NDF forward exchange rate began rising faster than the spot rate, indicating that the market was anticipating depreciation of the won.[6] On the other hand, the domestic forward exchange rate continued to move closely with the spot rate. This might be in part due to the thinness and inefficiency of the domestic forward market, but was

[5] McCormick (1979) and Clinton (1988) discuss empirical evidence supporting the covered interest parity.
[6] However, the one-month forward premium never exceeded 20 won per dollar from July to October 1997, indicating that what investors anticipated was not a currency crisis but a smooth depreciation of the won. Only in late October did the international capital market anticipate the upcoming crisis in Korea and the forward premium take a big jump.

mostly attributable to the active forward intervention by the Bank of Korea.[7]

< Figure 1: The won-dollar Spot and Forward Exchange Rates >

We propose four different methods of computing the implied spot exchange rate from the covered interest parity.

## II.1 Method I

The first method uses the observed interest rates on won-denominated and dollar-denominated bonds to calculate the implied spot exchange rates from the NDF forward exchange rates. Let $S_t$ denote the spot exchange rate of the Korean won expressed as the units of the Korean won per U.S. dollar. Let $F_{n,t}$ stand for its n-month forward exchange rate at the NDF market, $i_{n,t}$ the annualized interest rate on won-denominated bonds with n-month maturity, and $i^*_{n,t}$ the annualized interest rate on dollar-denominated bonds with n-month maturity at time t, respectively. If capital is perfectly mobile across borders, the following covered interest parity should hold:

$$F_{n,t} = S_t (1 + i_{n,t}\, n_M)/(1 + i^*_{n,t}\, n_M) \quad \text{, where } n_M = \text{n/12} \qquad (1)$$ [8]

However, it is important to remember that investors are covered only from the exchange rate risks in the covered interest parity. The domestic interest rate in the parity is only a promised interest rate. It does not necessarily reflect the expected return for foreign investors especially during a currency crisis when political and default risks get significantly large. Therefore, we have to adjust the covered interest rate parity by explicitly considering these risks before applying our method. Let $p_t$ denote the probability that a won-denominated bond will be on default within a year from time t and let $\chi$ denote the salvage value expressed as proportion of initial investment in case of default. $\chi$ is a number between 0 and 1. In general, $\chi$ is not equal to zero since there exists

[7] Park and Rhee (1998) discuss the timing and the magnitude of foreign exchange market intervention by the Bank of Korea in this period.

[8] $n_M$ is introduced to convert annualized interest rats to an effective n-month rates. N-month interest rates are

possibility of debt rescheduling or debt restructuring in practice. In section III.1, we will explain how $p_t$ and $\chi$ are estimated but for the time being, let us assume that they are known parameters. If we assume that foreign investors are risk neutral and require the same expected rate of return from domestic and foreign investment, the following default risk-adjusted covered interest parity should hold:[9]

$$F_{n,t} = S_t \{(1+i_{n,t}\, n_M)(1-p_t\, n_M)+\chi\, p_t\, n_M\}/\{1+i^*_{n,t}\, n_M\} \text{ , where } n_M = \text{n/12} \qquad (1')$$

By treating the forward exchange rates and the interest rates as exogenous, we can calculate the implied spot exchange rate, $\hat{S}_t$, which satisfies the risk adjusted parity condition (1'):

$$\hat{S}_t = \frac{F_{n,t}(1+i^*_{n,t}n_M)}{[(1+i_{n,t}n_M)(1-p_t n_M)+\chi p_t n_M]} \qquad (2)$$

We measure the degree of currency misalignment by the ratio of the implied spot exchange rate to the observed rate, $\hat{S}_t / S_t$. If $\hat{S}_t / S_t$>1, the observed spot exchange rate is lower than the level that participants in the NDF market expect to prevail and it indicates that the Korean won is overvalued against the dollar.[10] On the other hand, if $\hat{S}_t / S_t$<1, we interpret that the Korean won is undervalued against the dollar.

## II.2 Method II

Method I uses the observed and foreign interest rates to compute the implied spot exchange rates. Thus, it implicitly assumes that foreign investors have unrestricted access to the domestic security market and that the observed domestic interest rates properly reflect the rate of return that foreign investors expect to earn by investing in won-denominated bonds in Korea. However, the won-denominated bond market in Korea had not been fully open to foreigners until after the crisis, so the

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approximated as n/12 of the annualized interest rates.

[9] Since $i^*_{n,t}$ is the risk-free foreign interest rate, equation (1) is true only when foreign investors are risk neutral.

[10] Note that all exchange rates are in terms of the Korean won against the US dollar.

observed domestic interest rates may not properly reflect the rate of return that foreign investors could earn by investing in Korea.[11]

Moreover, during the Korean crisis, the domestic interest rates were heavily regulated and a severe credit crunch widened the interest rate differential between the curb market and the institutionalized market. Therefore, the observed domestic interest rates could not properly represent the market rate of return for domestic investors let alone for foreign investors. To the extent that domestic investors could have demanded higher curb market premium at that time, we believe foreign investors could have done the same in the won-denominated bond market.

Since the observed domestic interest rates seem to be a poor measure of the rate of return from investing in won-denominated bonds, Method II tries to infer the domestic interest rates directly from the covered interest parity.[12] In other words, Method II calculates simultaneously the implicit spot exchange rate and the domestic interest rates that satisfy the covered interest parity. To do that, we need to use more than one no-arbitrage condition and thereby rely on the covered interest parities that hold for forward exchange contacts with different maturities. For example, equations (3) and (4) are the risk adjusted covered interest parities between the spot and the forward exchange rates with 3 and 6 month maturities, respectively.

$$F_{3,t} = S_t \{(1+i_{3,t}\, n_3)(1-p_t\, n_3)+\chi\, p_t\, n_3\}/\{1+i^*_{3,t}\, n_3\} \text{ , where } n_3 = 1/4 \qquad (3)$$

$$F_{6,t} = S_t \{(1+i_{6,t}\, n_6)(1-p_t\, n_6)+\chi\, p_t\, n_6\}/\{1+i^*_{6,t}\, n_6\} \text{ , where } n_6 = 1/2 \qquad (4)$$

If the yield curve of the domestic interest rates is flat, i.e., if the condition $i_{6,t} = i_{3,t}$ holds, then we can calculate the implied spot exchange rate, $\hat{S}_t$, and the implied interest rate, $\hat{i}_{n,t}$ (n = 3, 6) from equations (3) and (4). As in Method I, the ratio of the implied spot exchange rate to the observed rate, $\hat{S}_t / S_t$, is the measure of currency misalignment. We will also analyze the behavior of the difference between the implied and the observed domestic interest rates, $\hat{i}_{n,t} / i_{n,t}$.

[11] This does not necessarily mean that arbitrage was not possible between the NDF and the domestic forward exchange market prior to the crisis. As we will see shortly, the covered interest rate parity was satisfied reasonably well prior to the crisis.

[12] Method II continues to assume that observed interest rates on dollar-denominated deposits properly reflect foreign investors' opportunities.

## II.3 Method III

It seems unrealistic to assume that the term premium was zero especially during such a turbulent period like a financial crisis. Credit crunches, increased uncertainty, and changes in expected inflation rates make short-term interest rates and the slope of the yield curve change wildly. Method III introduces a non-zero but constant term premium $\alpha$ to method II.

$$i_{6,t} = i_{3,t} + \alpha \qquad (5)$$

Since another unknown parameter $\alpha$ is introduced, we need one more condition; we assume that the sample mean of the implied three month interest rates on won-denominated bonds is equal to the sample mean of the observed three month interest rates:

$$\sum_t \hat{i}_{3,t} = \sum_t i_{3,t} \qquad (6)$$

To check the robustness of our empirical results, different sample periods will be examined in applying equation (6).[13] In summary, Method III calculates the spot exchange rate, the domestic interest rates, and the term premium from equations (3), (4), (5) and (6).

## II.4 Method IV

To calculate the constant term premium $\alpha$, Method III has to choose a specific sample period to equate the sample mean of the implied interest rates with that of the observed rates. Instead of relying on this arbitrary assumption, Method IV calculates the unknown term premium by using additional covered interest parity for a different maturity. For example, in addition to the covered interest parities for 3-month and 6-month maturities, Method IV uses one more parity condition for

[13] Alternatively, we can use equation (6'), which explicitly considers the sovereign default probability and equalizes the expected returns. The estimated results, however, are very similar.

a forward contract with 1-month maturity.

$$F_{1,t} = S_t \{(1+i_{1,t}\, n_1)(1-p_t\, n_1)+\chi\, p_t\, n_1\}/\{1+i^*_{1,t}\, n_1\} \text{ , where } n_1 = 1/12 \qquad (7)$$

Like Method III, we still assume that the slope of the yield curve is constant at time t as expressed in equations (8) and (9). But, in Method IV, the monthly term premium, $\beta_t$, is time-varying.

$$i_{3,t} = i_{1,t} + 2\beta_t \qquad (8)$$

$$i_{6,t} = i_{1,t} + 5\beta_t \qquad (9)$$

From equations (3), (4), (7), (8) and (9), Method IV calculates the implied spot exchange rate, the domestic interest rates, and the term premium while treating the forward exchange rates and the foreign interest rates as exogenous.

Among the four methods, we think Method I is inferior to the other three since the observed domestic interest rates did not properly reflect the rate of return that foreign investors could get from investing in won denominated assets. Considering the severity of the dual structure of the Korean financial market during the crisis, we prefer to estimate the domestic interest rates rather than use the heavily regulated observed domestic interest rates. Also, Method IV seems superior to Methods II and III since it allows time varying term premiums. However, Method IV has its own weakness. Our methodology relies on the presumption that NDF exchange rates were relatively unaffected by the exchange market intervention of the Korean government. This presumption might be less valid for the forward exchange rates with shorter maturity if investors believe intervention policy could be effective at least in the short run; therefore, Method IV might be less valid than Methods II and III. In interpreting the empirical results, we will treat Methods II, III and IV equally and use Method I as a benchmark for comparison.

## III. Empirical Results

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$$\sum\left[(1+\hat{i}_{3,t}\, n_3)(1-p_t n_3)+\chi p_t n_3\right] = \sum(1+i_{3,t}\, n_3) \qquad (6')$$

### III.1 Default Probability

In this section, we explain how we estimate the default probability of won denominated bonds, $p_t$, and the proportion of salvage value from initial investment, $\chi$. Before the crisis erupted, the won-denominated government bond market in Korea was completely closed to foreigners, so that their yield could not properly reflect the rate of return that foreign investors could earn by investing in Korea. Therefore, in our covered interest parity condition, we consider the foreign investors who invested on the won-denominated private bonds issued by large Korean conglomerates (Chaebols) or big financial institutions. We assume that the default probabilities of these large conglomerates or financial institutions were equal to the sovereign default probability of Korea.[14]

Sovereign default in general means the government's inability to pay back its foreign currency denominated debts, and it has conceptually nothing to do with the default of the local currency denominated debts. However, by assuming that the default probabilities of the won denominated and foreign currency denominated debts are equal, we are implicitly assuming that large conglomerates or financial institutions will bankrupt and default their private debts if sovereign default occurs. This assumption seems consistent with a long-standing tradition of the credit rating industry to observe the sovereign ceiling, that is, no corporate debt has a rating higher than that of the home government.

The sovereign default probability of Korea can be inferred from the yield spread between a dollar denominated Korean government bond and the U.S. Treasury bond of a similar maturity, which is a generally accepted measure of sovereign risk premium. However, since the Korean government began to issue dollar-denominated bonds only in the beginning of 1998, we use the Korean Development Bank (KDB)'s global bonds to estimate the sovereign default probability. The KDB is owned by the government and its bonds have been treated as a near-sovereign benchmark security for Korea in the international capital market for a long time.

Figure 2 shows that the yield spread between the KDB bond and the U.S. Treasury bond was less than 1 percent in the first half of 1997. However, after the Thai crisis erupted in July 1997, it began rising sharply and reached 5 percent at the peak of the Korean crisis in December 1997. After the debt restructuring deal was made between the Korean government and the creditor group in New

[14] Given the existence of a few dominant conglomerates in the Korean economic structure and the implicit

York in January 1998, the yield spread declined temporarily. But it soared again as soon as the international financial turmoil worsened and a new round of financial crises in Russia and Brazil started in the second half of 1998. The yield spread peaked in October 1998, reaching almost 9 percent.

< Figure 2: The Yield Spread of the KDB Global Bond >

From the yield spread on KDB bonds, we can compute the implied probability of the sovereign default of Korea as follows. Let $p_t$, $i_{KDB}$ and $i_{TB}$ be the sovereign default probability of Korea within a year, and the annualized interest rates of the KDB and the U.S. Treasury bonds, respectively. If foreign investors are risk neutral and demand the same expected rate of return from domestic and foreign investment, the following condition should be satisfied.

$$(1+i_{TB,t})^n = (1+i_{KDB,t})^n(1-p_t)^n + (1+i_{KDB,t})^n \chi[1-(1-p_t)^n] \qquad (10)$$

In equation (10), n denotes the maturity of the bonds and we implicitly assume that the bonds are kept until maturity.[15] By plugging in the observed yield spread of the KDB bond and choosing an appropriate number for $\chi$, we can calculate the implied probability of sovereign default from equation (8). Figure 3 shows the estimated default probabilities when $\chi$ is set to 0.0, 0.25, and 0.5. Judging from the recent debt restructuring outcomes between the Korean government and the foreign creditors, it seems realistic to assume that $\chi$ is not larger than 0.4.[16] Not surprisingly, the estimated probabilities show the same pattern as that of the yield spread on the KDB bond presented in Figure 2. It is noteworthy that the foreign investors' estimates of the default probability reached its peak when a new round of emerging market financial crises started in Russia and Brazil in the

government guarantees on financial institutions, this assumption does not seem to be unreasonable.

[15] Under an alternative assumption that the bonds are sold before maturity, we can use equation (10'). Equation (10') implicitly assumes that the yield to maturity of a long term bond is equal to the rate of return that an investor expects to earn even if the bond is sold before maturity. The estimated sovereign default probabilities turn out to be not sensitive to the use of equation (10) or (10'), but are sensitive to the choice of $\chi$.

$$(1 + i_{TB,t}) = (1 + i_{KDB,t})(1 - p_t) + \chi\, p_t \qquad (10')$$

[16] For example, on January 22, 2000, the Korean Restructuring Coordination Committee (KRCC) and Daewoo foreign creditors' steering committee agreed on a recovery rate of 39 to 40 percent of loans made to Daewoo corporation without any collateral.

middle of 1998, long after the financial crisis erupted in Korea. In the following, we are going to assume that the estimated sovereign default probability is equal to the default probability of the won denominated bonds.

< Figure 3: Sovereign Default Probability >

### III.2 Observed and Implied Spot Exchange Rates

Figure 4 depicts the ratios of the implied spot exchange rates to the observed spot rates, $\hat{S}_t / S_t$, from August 1996 to March 1999. These ratios are calculated by the four methods introduced in section II. $\hat{S}_t / S_t$>1 indicates that the Korean won is overvalued against the U.S. dollar. Our data set consists of the NDF exchange rates, LIBORs and the won-denominated CD interest rates with 1, 3, and 6 month maturities.[17] To estimate the term premium $\alpha$ in Method III, the pre-crisis sample period from August 1996 to July 1997 is used in equating the sample means of the observed domestic interest rates with that of the implied interest rates.[18] July 1997 was the point at which the crisis in Thailand started to spread to other Asian countries. In Figure 4, we show the results when $\chi$ is equal to 0.25 as a representative case. For the other values of $\chi$, the results are quite similar; we report the corresponding figures and tables when $\chi$ is equal to 0 in the appendix.

< Figure 4: The Degree of Currency Misalignment >

Several features of the figure are worth noting. First, the movement of the $\hat{S}_t / S_t$ ratio shows similar patterns across all four methods. In particular, the ratio $\hat{S}_t / S_t$ had been quite close to one

[17] The qualitative aspects of the empirical results are quite robust to the choice of interest rates. Use of the U.S. T-bill rates instead of LIBOR and use of other domestic interest rates such as the call rates, the monetary stabilization bond yields, etc., provides similar results.

[18] Two other sample periods - the whole sample period and the post crisis sample period - are examined also, but the results in Figure 4 do not change much. This does not mean that the estimated term premium $\alpha$ is close to zero. To the contrary, the estimated term premium is sensitive to the choice of sample periods. However, the difference in $\alpha$ does not greatly affect the magnitude and the behavior of the implied spot exchange rate.

until the Thai crisis started in July 1997, indicating that the *de facto* arbitrage between the onshore and the offshore forward exchange markets was effective and the covered interest parity held reasonably well prior to the crisis.[19] Therefore, adopting a methodology based on the covered interest parity is not totally unrealistic even though the domestic bonds market in Korea was not fully open to foreign investors prior to the crisis.

Second, Figure 4 shows that the Korean won was sharply overvalued during the period between the eruption of the Thailand crisis in July 1997 and Korea's signing of a stand-by arrangement with the IMF on December 1, 1997. The degree of overvaluation against the U.S. dollar as of November 1997 is estimated to be as large as 8 to 11 percent according to Method I, II and III. Method IV presents a smaller degree of overvaluation of 4 percent. It turns out that the smaller degree of overvaluation from Method IV is largely attributable to its use of the one month forward exchange rates rather than the difference in the methodology *per se*. When one and three month forward rates are used instead of three and six month forward rates in Method II and III, the degree of overvaluation decreased from 8 to 6 percent. As previously noted, the NDF exchange rates with shorter maturity were more likely to be affected by the anticipation of intervention in the onshore exchange markets by the Korean government than the NDF rates with longer maturity. In other words, compared with the forward rates with longer maturity, the one month forward exchange rates may have depreciated less than they should have on the eve of the crisis. If this is the case, the one month forward rates make the spot exchange rates look relatively less overvalued than do the forward rates with longer maturity. The fact the difference of the degree of currency misalignment is not large across Methods II, III and IV except on the eve of the crisis indirectly supports our interpretation.

In summary, the estimated degree of currency overvaluation on the eve of the Korean crisis is significantly larger than those found in other studies, which do not exceed 4 percent (Chinn (1998), Goldstein (1998), Goldfajn and Baig (1998), and Lee (1997)). We believe that the overvaluation of the won was mostly attributable to the heavy foreign exchange market intervention by the Bank of Korea (BOK) from October to November 1997.[20] Despite its effort to uphold the value of the won, Figure 4 shows that the investors in the NDF market started to anticipate immediate and sharp depreciation of the Korean won from October 1997.

Third, the Korean won was undervalued in the beginning of 1998. At the peak of the country's

[19] For the pre-crisis period, the covered interest parity held reasonably well without adjusting for the sovereign default probabilities.

crisis in December 1997, the Korean won lost 70 percent of its value against the dollar in a month.[21] Figure 4 indicates that this sharp nominal depreciation was beyond the expectation of NDF market participants. However, the degree of under-valuation is not large compared with the degree of overvaluation prior to the crisis. In January 1998, the Korean won was estimated to be about 1-2 percent undervalued depending on the methods.

Fourth, from the middle of 1998 the Korean won became overvalued again. This was a period in which the Korean government started to lower domestic interest rates aggressively and a new round of financial crises in emerging markets started in Russia and Brazil. However, the degree of won overvaluation during this period differs significantly among the four methods. It is estimated to be 6 percent in June 1998 according to Method I. But the estimates from Methods II, III and IV are less than 2 percent. The discrepancy indicates that the observed and the implied interest rates on won-denominated bonds differ significantly, as we will see shortly. From July 1998 the degree of overvaluation started to decline and, at the end of 1998, the implied spot exchange rates in Methods II, III, and IV became close to the observed rates again as they were before July 1997. On the other hand, Method I indicates that the spot exchange rates were still slightly overvalued at the end of 1998.

### III.2 Covered Interest Rate Differential

The fact that $\hat{S}_t / S_t$ is not equal to 1 implies that there are unrealized opportunities for arbitrage. Even though the informational contents are the same, it would be helpful to express our measure of currency misalignment in terms of the covered interest rate differential. Equation (11) defines the covered interest rate differential ($CID$) when the forward exchange rates with n month maturities are used.

$$CID_t = [(1 + i^*_{n,t} n_M) - \{(1 + i_{n,t} n_M)(1 - p_t n_M) + \chi p_t n_M\} \frac{S_t}{F_{n,t}}] / n_M \text{ , where } n_M = n/12. \qquad (11)$$

The $CID$ measures the annualized extra rate of return that investors could make by switching

[20] Park and Rhee (1998) summarize the chronology and the magnitude of the BOK intervention in this period.
[21] The spot exchange rates depreciated from 1,112 to 1,965 won per U.S. dollar between November 28 and

investment from won-denominated bonds to dollar-denominated bonds. Figure 5 shows the movement of the $CID$ and Table 1 presents its mean values for various sample periods. The $CID$ labeled as Method I is derived using the observed 3 month CD rate as the domestic interest rate in equation (11). The $CIDs$ labeled as Methods II, III and IV are computed using the implied domestic interest rates with 3 month maturities from Method II, III and IV, respectively.[22]

< Figure 5: Covered Interest Rate Differential>

< Table 1: Covered Interest Rate Differential>

Needless to say, the movement of the covered interest rate differential in Figure 5 should be identical to that of the $\hat{S}_t / S_t$ ratio in Figure 4. But the degree of currency misalignment is expressed in terms of the annualized interest rates in Figure 5 and Table 1. Before July 1997, the $CID$ was close to zero and the covered interest parity seemed to hold reasonably well. However, it increased sharply starting from July and came to be as large as 18 to 40 percent in November 1997. It is not surprising that there were large capital outflows from Korea at that time.

In the beginning of 1998, due to the drastic depreciation of the Korean won and the sharp increase in domestic interest rates, the covered interest differential turned negative, which means that investing in won-denominated bonds became more attractive. However, the magnitude of the covered interest differential varies widely across different methods. Between January and March 1998, Method I indicates that investing in won-denominated bonds was about 6.4 percent more profitable than investing in dollar-denominated assets. However, Methods II, III and IV indicate that the profit margins are smaller at only 3.1, 5.9, and 2.4 percent, respectively.

In the middle of 1998, the Korean won came to be overvalued again, and the covered interest rate differential became positive. According to Method 1, the interest rate differential was 16 percent during this period. That estimate was as high as the estimates of $CID$ in November 1997, the month just before the crisis erupted. However, the estimates for $CID$ by Methods II, III, and IV are only 4.9, 2.1 and 2.6 percent, respectively. At the end of 1998, the covered interest rate differential declined and became close to zero again according to Methods II, III and IV.

In summary, the movement of the $\hat{S}_t / S_t$ ratio and the covered interest differential imply the

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December 23, 1997.

[22] In both cases, the observed spot exchange rates are used in calculating the CID in equation (11), and not the

following facts. [1] Before the Asian crisis started in July 1997 and after the Asian financial markets showed signs of stability at the end of 1998, the covered interest rate parity held reasonably well. [2] At the end of 1997 when the Korean crisis was at its peak, the Korean won was significantly overvalued; the covered interest rate differential indicates that investing in dollar-denominated bonds was more profitable. [3] In the beginning of 1998, the Korean won was undervalued and investing in won-denominated bonds was more profitable. [4] In the middle of 1998, the Korean won came to be overvalued again and investing in dollar-denominated bonds was more profitable.

Although the four methods show qualitatively similar patterns as summarized above, there still exist significant differences in their estimates, and the discrepancy seems relatively large especially for facts [3] and [4]. Since the differences across the methods are largely due to their choices of the domestic interest rates, we will compare the movement of the observed domestic interest rates with the implied interest rates derived from the covered interest parities.

### III.3 Observed and Implied Domestic Interest Rate

Figure 6 compares the behavior of the observed interest rates on won-denominated bonds with the implied values calculated by Methods III and IV. Method III is different from Method II in that it allows a non-zero term premium for domestic interest rates. However, since the implied interest rates of Methods II and III turn out to be quite similar, the result from Method II is not reported separately in Figure 6.

< Figure 6: Observed and Implied Domestic Interest Rate >

As can be seen in Figure 6, the pre-crisis average 3-month CD rate was 14 percent but it soared sharply after November 1997. At the peak of the crisis in January 1998, it recorded 23 percent. Following the gradual shift in monetary policy from austerity to easy stance in the middle of 1998, it declined steadily and became lower than the pre-crisis level from August 1998. However, the implied interest rates from Method III and IV show a very different pattern. They increased sharply from September to November 1997 long before the surge of the observed rate. Besides, they decreased, not increased, in the beginning of 1998 and soared again in the middle of 1998, even though the observed interest rates started to decline sharply during this period. Only at the end of

implied spot exchange rates. If implied spot exchange rates are used, CID should be zero by definition.

1998 did the implied rates converge to the observed rate.

Conceptually the implied domestic interest rates represent the rates of return that foreign investors demand from won-denominated bonds in Korea. As explained in section II, they need not be equal to the observed domestic CD rates that were heavily regulated and whose payment was guaranteed by the government during the crisis. To the extent that domestic investors could demand higher curb market premiums over the regulated interest rates at that time, we believe foreign investors could have done the same in the won-denominated bond market.

Thus it is not surprising to see that the implied domestic interest rates in Figure 6 show the same pattern as that of the sovereign default probability in Figure 3. As the sovereign risk sharply increased at the end of 1997, foreign investors could have asked for a higher risk premium for investing in won-denominated bonds. The severe credit crunch problem and the excess demand for foreign funds must have made it easier for foreign investors to selectively choose blue chip companies and ask simultaneously for higher premiums. The behavior of the implied interest rate in 1998 can be explained in a similar way. Despite the sharp decrease in the regulated interest rates due to expansionary monetary policies from the middle of 1998, the implied interest rates soared again as the international financial turmoil went into another turmoil. As the sovereign risk on Korea rose together with other emerging market countries, foreign investors could have demanded a higher premium on their won denominated investment.[23]

The validity of the above interpretation can be checked if we can observe the curb market interest rates charged on large conglomerates or financial institutions. However, given the lack of appropriate data, we try to estimate the upper and lower bounds of the curb market premium by considering the two extreme cases. In Korea, 3 month CD interest rate was a good proxy for the risk free interest rates prior to the crisis and the average of the 3 month CD interest rate was about 14 percent prior to the crisis. Our first extreme assumption is that the risk free interest rates did not change after the crisis erupted and that risk neutral investors asked for the same 14 percent expected rate of return from their curb market investment. Then the curb market risk premium, $\phi_{1,t}$, had to satisfy equation (12), where the default probability of the hypothetical won-denominated bonds is assumed to be equal to the sovereign default probability.

$$(1+0.14) = (1+0.14+\phi_{1,t})(1-p_t) + \chi\, p_t \qquad (12)$$

[23] We have to admit that this hypothesis cannot explain why the implied interest rates are lower than the actual CD rates in the beginning of 1998.

In calculating $\phi_{1,t}$ from equation (12), $\chi$ is assumed to be 0.25 or 0.5 since we do not know whether the proportion of salvage value should be higher or lower in case of private corporation's default compared with sovereign default. The risk premium adjusted domestic interest rates, 0.14 + $\phi_{1,t}$, are plotted in Figure 7. The series I and II correspond to the rates when $\chi$ is equal to 0.25 and 0.5, respectively.

So far, we implicitly assume that the pre-crisis risk free interest rates did not change even after the eruption of the crisis. However, considering tight monetary policy and severe credit crunch, that assumption seems unrealistic. As the other extreme case, assume that the observed CD interest rate was a good proxy for the risk free interest rates even after the crisis erupted and the curb market investors asked for the same expected rate of return as the observed CD rate. Then the curb market risk premium, $\phi_{2,t}$, satisfies the following condition.

$$(1 + i_t) = (1 + i_t + \phi_{2,t})(1 - p_t) + \chi\ p_t \qquad (13)$$

In equation (13), $i_t$ denotes the observed CD interest rate and $i_t + \phi_{2,t}$ is our second measure of the risk premium adjusted domestic interest rate. It is plotted in Figure 7 and the series III and IV are the rates when $\chi$ is equal to 0.25 and 0.5, respectively. We believe the true risk premium adjusted interest rates should be between the two extreme cases shown in Figure 7.

We find the results in Figure 7 quite comforting. The risk premium adjusted interest rates show a pattern similar to that of the implied interest rates in Figure 6. Even though they cannot fully explain the first hump of the implied interest rates at the end of 1997, they seem to explain quite well the second hump in the middle of 1998. In particular, when $\chi$ is set to 0.5, the risk premium adjusted interest rates explain a significant portion of the difference between the observed and the implied domestic interest rates.[24] This is a supporting evidence for our interpretation that the observed CD rates cannot properly reflect the rate of return that foreign investors expected to earn by investing in won denominated bonds, while the implied interest can.

< Figure 7: Observed and Risk Adjusted CD Rates >

[24] The magnitude of the implied interest rates in Figure 6 does not change much if we vary $\chi$ from 0.25 to

## IV. Currency Misalignment and Capital Inflows

The degree of currency misalignment and the covered interest rate differential indicate which direction foreign capital should flow. This section examines the pattern of capital flows during the Korean crisis to see whether they moved as predicted. Figures 8 and 9 show the monthly capital flows from January 1997 to January 1999. Since investment abroad by domestic residents in Korea was more or less restricted during that period, we only look at investment by foreigners.[25] We also exclude borrowings from international financial institutions and foreign governments in order to focus on private capital flows.

Figure 8 shows foreign capital flows by investment type: foreign direct investment, portfolio investment, and other investment. Figure 9 breaks down portfolio investment into equity and bond investment. Other investment consists of largely short-term and long-term external borrowings of domestic financial institutions and accounts for the lion's share of capital outflows at the peak of the Korean crisis. The figure shows that currency speculation played only a limited role; the failure to roll over external debt of domestic financial institutions was the main cause of capital outflows in the crisis.

< Figure 8: Foreign Investment by Type >

< Figure 9: Foreign Portfolio Investment >

Figure 8 shows that the size of foreign direct investment was negligible and did not change significantly during the crisis period. In contrast, portfolio investment was volatile, with net inflows in the middle of 1997 and in the first half of 1998 and net outflows in the second half of 1997 and in the middle of 1998. If we consider portfolio capital flows alone, the degree of currency misalignment and the covered interest rate differential reported in section III are consistent with the direction of capital flows. However, the other investment categories that had larger shares in total capital flows did not fully conform to the changes in the covered interest rate differential. There were outflows of other investment at an accelerating pace after July 1997, reaching a peak in December 1997. Unlike portfolio investment, there was no reversal during the first half of 1998.

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0.5.

[25] Including net foreign investment by domestic residents does not change the results in this section.

Our measures of currency misalignment and the covered interest differential show a mixed performance in explaining the pattern of foreign capital flows. As summarized in Table 1, Method I estimates that the incentives for capital outflows in the middle of 1998 were as strong as that in the second half of 1997. The excess return from switching won-denominated investment to dollar-denominated investment is estimated as 16.3 percent in the middle of 1998 and 18 percent at the end of 1997, respectively. However, in contrast to this prediction, capital outflows in the form of equity investment and other investment were much larger in the second half of 1997 than in the middle of 1998. Only capital outflows in the bond investment category show similar magnitude in these two periods. Also, there was no sign of large capital inflows in the beginning of 1998 despite the fact that investing in won-denominated assets was estimated to be about 6.4 percentage point more profitable than investing in dollar-denominated deposits.

The finding that capital flows during the Korean crisis were not sensitive to interest rate differentials, and in particular that there was no reversal in capital flows in the beginning of 1998 despite high domestic interest rates, is frequently used as a case against the IMF adjustment program in Korea. The critics argue that, instead of bringing back foreign capital and stabilizing exchange rates, the tight macroeconomic policies of the IMF and the consequent high interest rates had a negative effect on a highly leveraged country such as Korea by deepening credit crunch problems.

Such criticism, however, is not justified by the results of Methods II and III. These two methods demonstrate that there were strong incentives for capital outflows in the second half of 1997. However, the estimated covered interest differentials in the beginning of 1998 and in the middle of 1998 are much lower if we use Methods II, III or IV. For example, Method IV estimates the excess return from investing in won-denominated bonds to be 2.4 percent in the beginning of 1998, whereas Method I estimates the excess return to be 6.4 percent. The excess return from investing in dollar-denominated deposits in the middle of 1998 is only 2.6 percent, not 16.3 percent, if we use Method IV instead of Method I.

In other words, Methods II, III and IV suggest that the incentives for capital inflows or outflows in 1998 were not as strong as the incentives indicated by Method I. Thus, it is not surprising to find that capital inflows in early 1998 and capital outflows in the mid-1998 were much smaller than the capital outflows in the second half of 1997. This implies that the problem did not lie in the low interest rate elasticity of foreign capital flows *per se*. The real problem was that, judging from the foreign investor's pessimistic perspective on Korea, the Korean won was depreciated too little, not

too much, and the Korean domestic interest rates increased too little to spark resumption of foreign investment. As emphasized by Stiglitz (1998), once a crisis starts, only unrealistically high and politically unacceptable high interest rates would be effective in comforting foreign investors and in defending exchange rates.[26]

## V. Conclusion

This paper proposes a method of measuring the degree of currency misalignment using offshore forward exchange rates. By treating the observed offshore forward exchange rates as exogenous, we calculate the spot exchange rates and the domestic interest rates implied from the covered interest parities and compare them with the observed ones. Our methodology is based on the presumption that, during a currency crisis, offshore forward exchange rates may reflect market fundamentals more closely than onshore ones that are usually tightly regulated and heavily affected by government intervention.[27] The implied spot exchange rates and domestic interest rates are interpreted as the ones that would have prevailed if there were no government intervention.

Differently from what others have concluded (Chinn (1998), Goldstein (1998), Goldfajn and Baig (1998)), our method indicates that the Korean won was significantly overvalued on the eve of the country's crisis in 1997. It also finds that the Korean won became undervalued in the beginning of 1998 due to sharp nominal depreciation, but that the degree of under-valuation was not large enough to spark the resumption of foreign capital inflows.

It is true that our measure of currency misalignment cannot address the important issue of optimality. It simply measures the deviation of the observed exchange rate from the level that the participants in the NDF market expect to prevail. If the NDF market is contaminated by an irrational bubble, herd behavior, etc, finding that the exchange rate is not misaligned according to our method does not imply that it is at an optimal level. However, for a small open economy with

[26] However, this argument does not imply that the IMF's high interest rate policy in Korea was a mistake. Other rationales for high interest rate policy exist apart from reversing foreign capital outflows. For example, Park and Rhee (1998) argue that at the peak of the crisis the high interest policy was necessary to stop the domestic financial institutions from buying dollars at the domestic exchange market with the won they borrowed from the central bank.

[27] In this respect, our methodology can be applied only to a country in which an onshore forward market is under-developed or does not exist and consequently has its currency traded heavily in offshore markets. Among the crisis-hit Asian countries, only Korea seems to satisfy this condition. The currencies of Indonesia, Malaysia, and Thailand are not traded in the Asian NDF market, whereas Chinese renminbi, Indian rupee, New Taiwan dollar, Philippine peso and Korean won are. It would be interesting to apply our method to some

insufficient foreign exchange reserves, our measure can be a useful index in judging whether it can successfully fight speculative attacks.

of these currencies, particularly, the Chinese renminbi.

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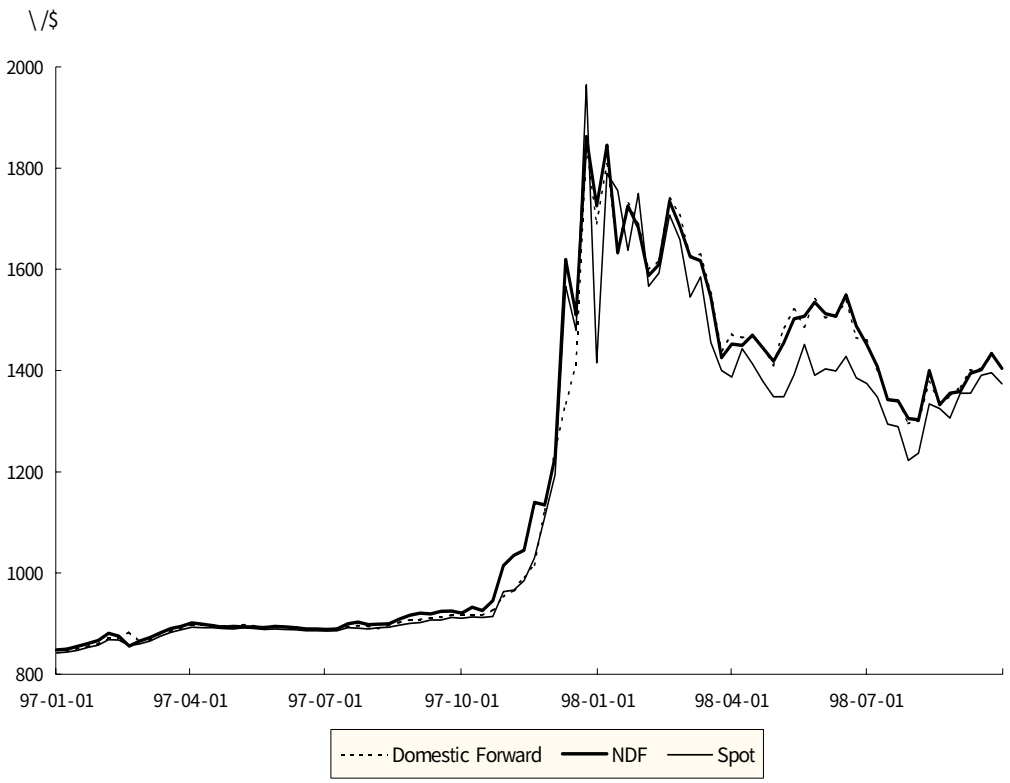
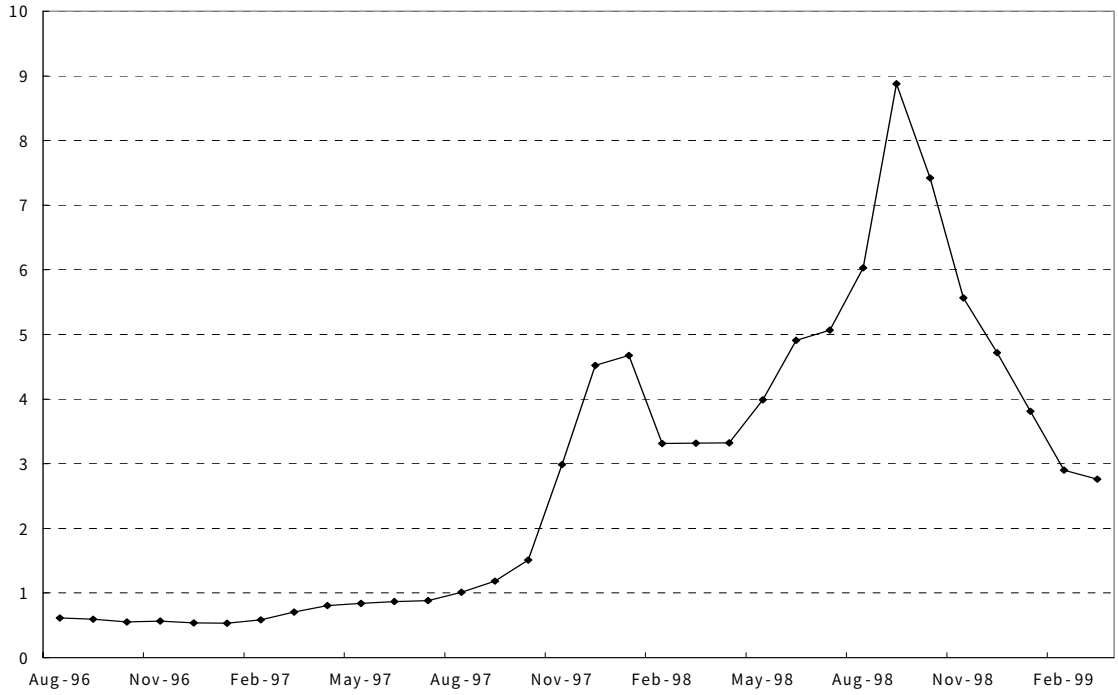
**<Figure 1> The Won-Dollar Spot and Forward Exchange Rates**

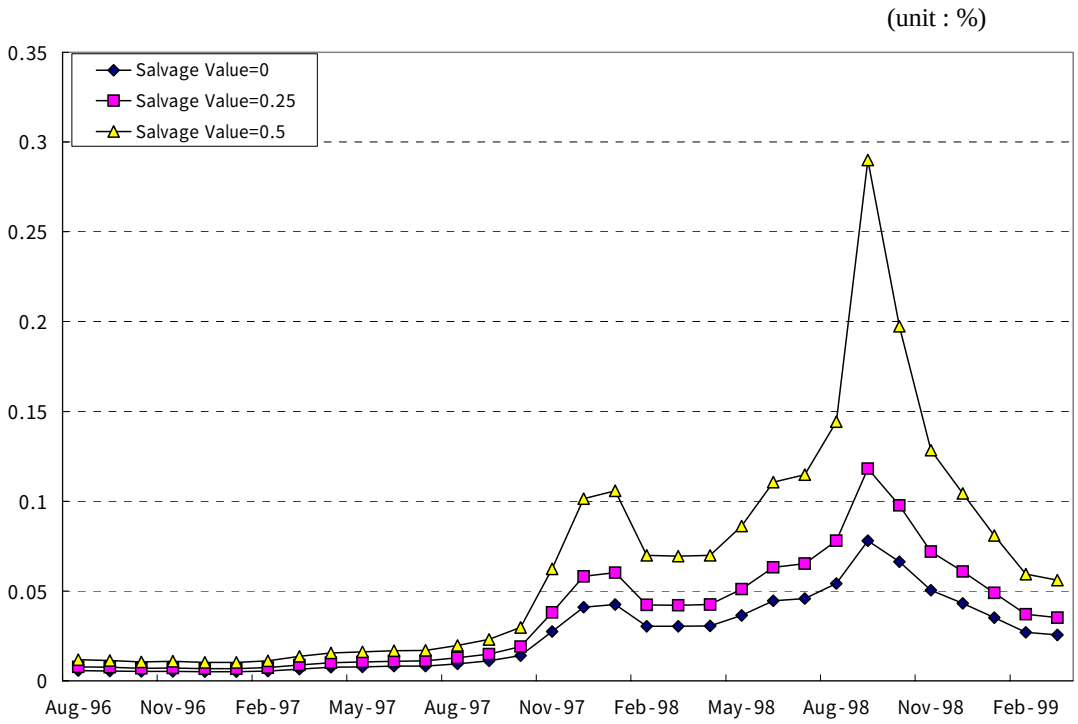


**<Figure 2> The Yield Spread of the KDB Global Bond**



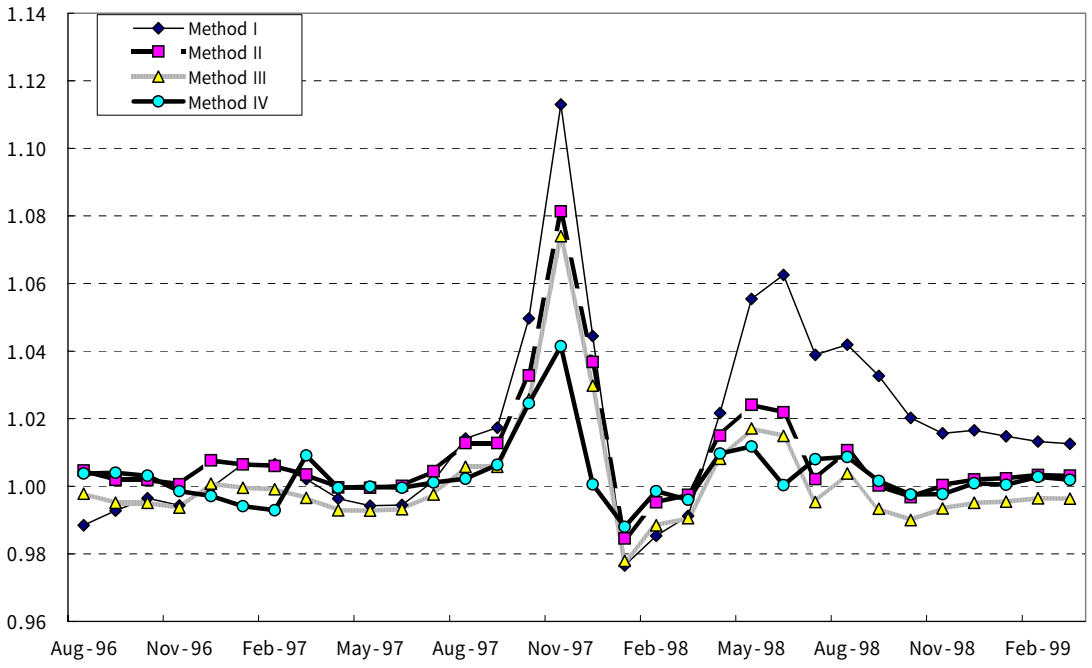

(unit : %)

**<Figure 3> Sovereign Default Probability**



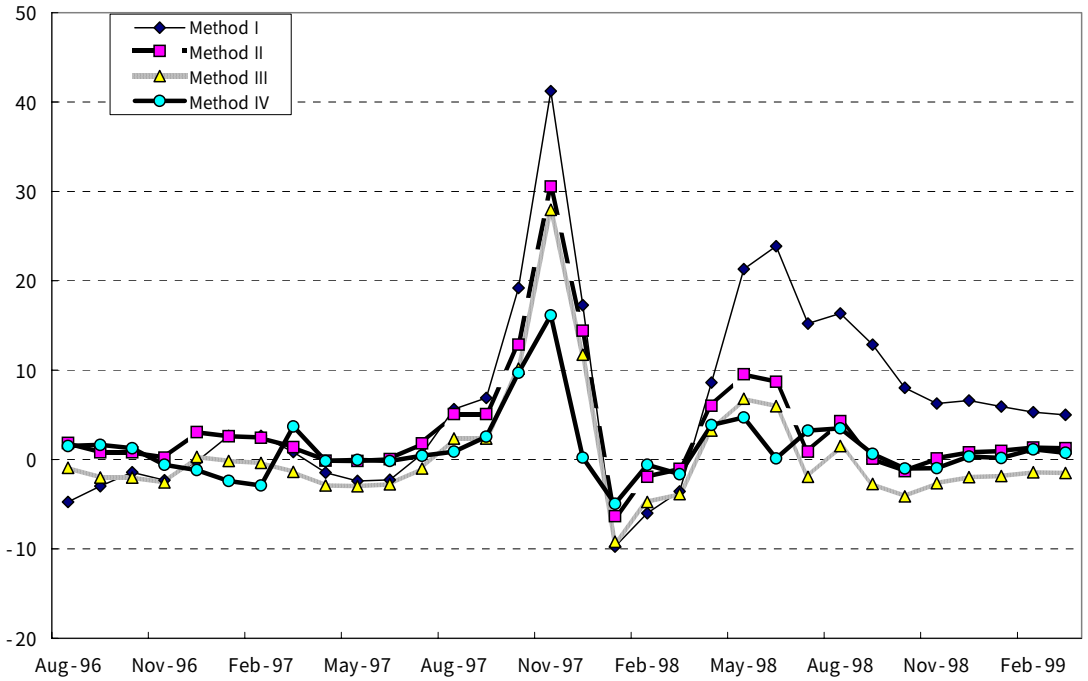

1) Probabilities are calculated using equation (10).

**<Figure 4> The Degree of Currency Misalignment**




1) LIBOR and CD rates are used as the interest rates on dollar-denominated and won-denominated deposits, respectively.
2) Salvage value, $\chi = 0.25$, is assumed.

**<Figure 5> Covered Interest Differential**




(unit : %)

1) LIBOR and CD rates are used as the interest rates on dollar-denominated and won-denominated deposits, respectively.
2) Salvage value, $\chi = 0.25$, is assumed.

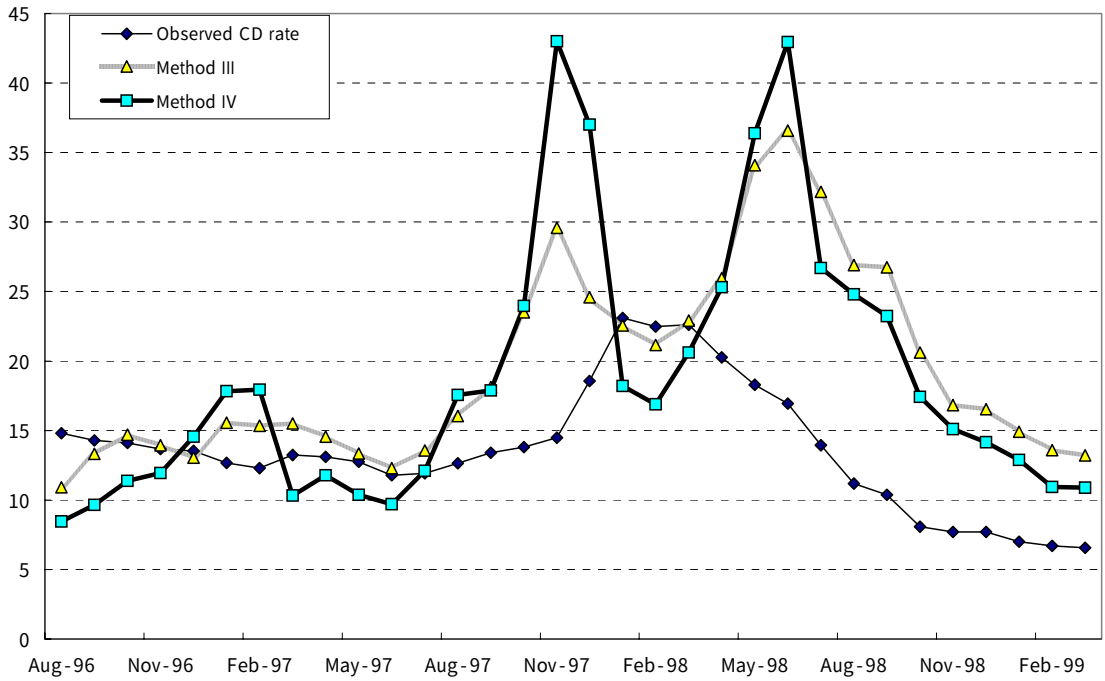
**<Table 1> Sample Mean of the Covered Interest Rate Differential**

(unit : %)

| | Method I | Method II | Method III | Method IV |
|---|---|---|---|---|
| Aug.96 – Jul.97 | -0.92 | 1.22 | -1.56 | 0.09 |
| Aug.97 – Dec.97 | 18.05 | 13.60 | 10.90 | 5.91 |
| Jan.98 – Mar.98 | -6.44 | -3.11 | -5.93 | -2.40 |
| Apr.98 – Sep.98 | 16.36 | 4.91 | 2.15 | 2.68 |
| Oct.98 – Mar.99 | 6.18 | 0.53 | -2.25 | 0.07 |

**<Figure 6> Observed and Implied Domestic Interest Rates**

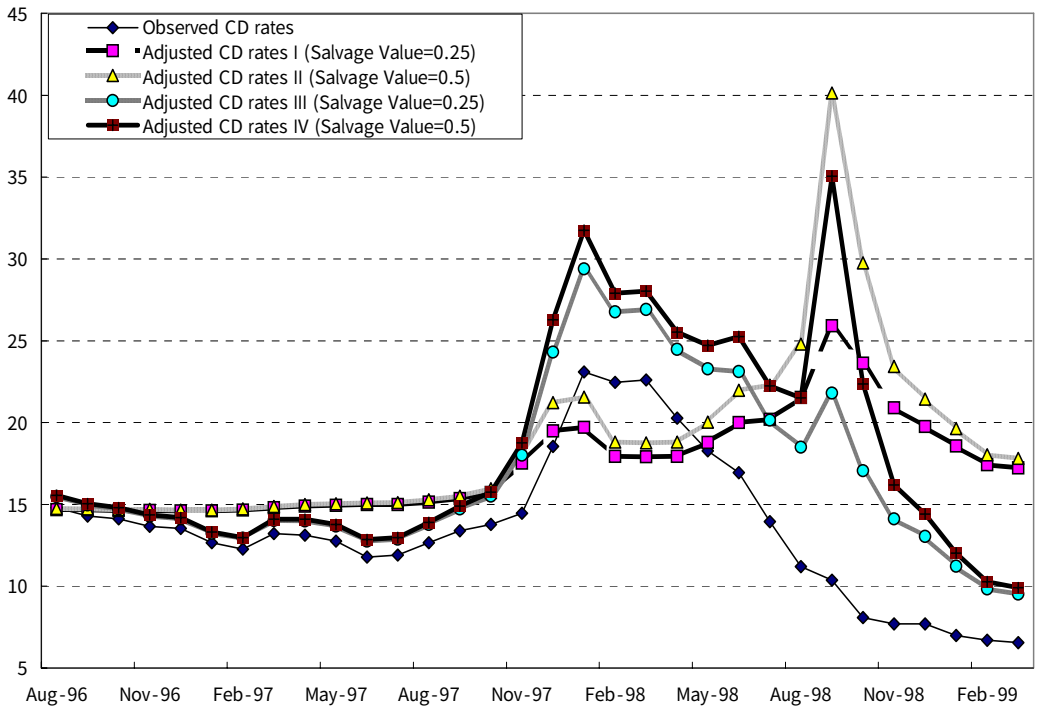
(unit : %)



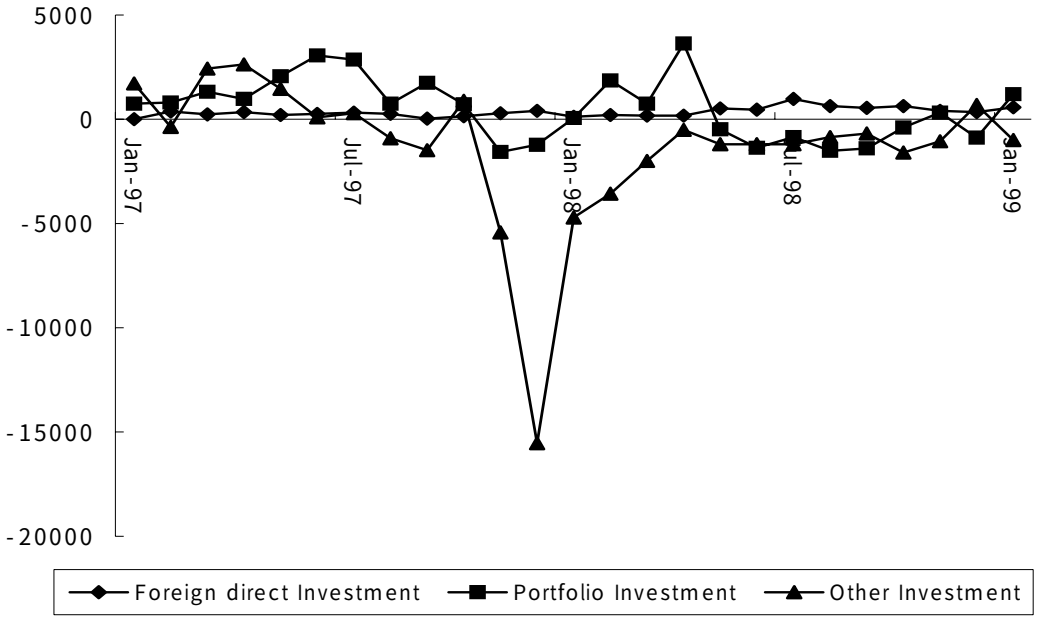

1) LIBOR and CD rates are used as the interest rates on dollar-denominated and won-denominated deposits, respectively.
2) Salvage value, $\chi = 0.25$, is assumed.

**<Figure 7> Observed and Risk Adjusted Domestic Interest Rates**

(unit : %)



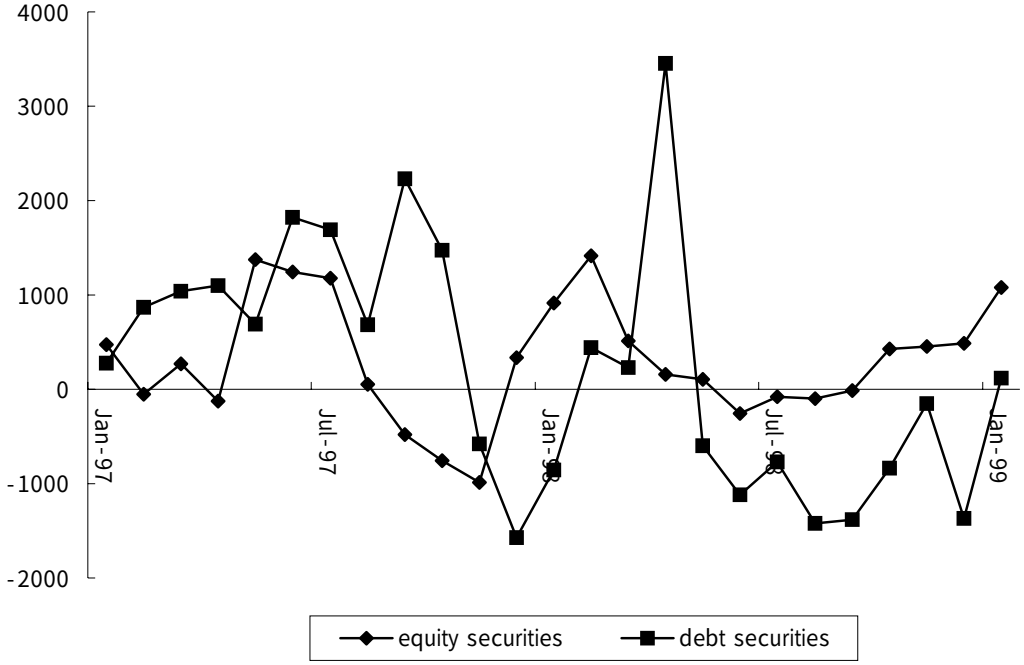
**<Figure 8> Foreign Investment by Type**




(unit: million U.S. dollar)

Source : Monthly Bulletin, The Bank of Korea.
1) General Government, Monetary Authorities and other liabilities are excluded from Foreign Other Investment.

**<Figure 9> Foreign Portfolio Investment**

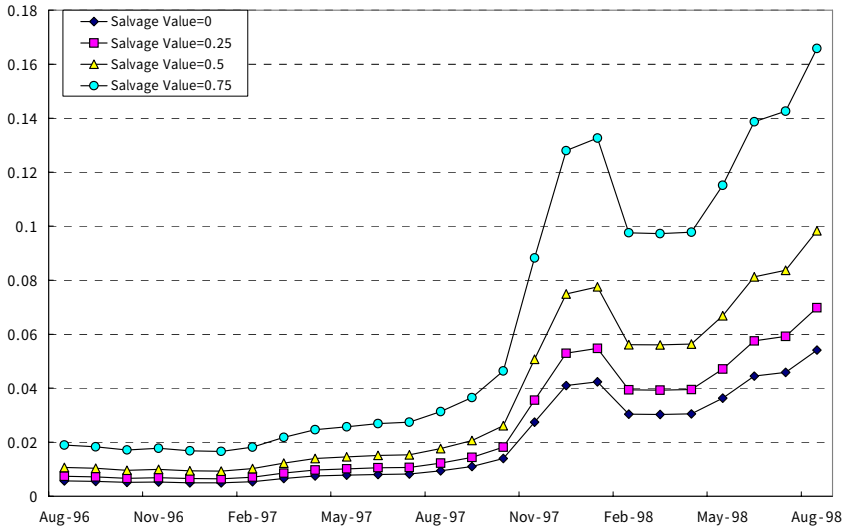



(unit: million U.S. dollar)

Source : Monthly Bulletin, The Bank of Korea.

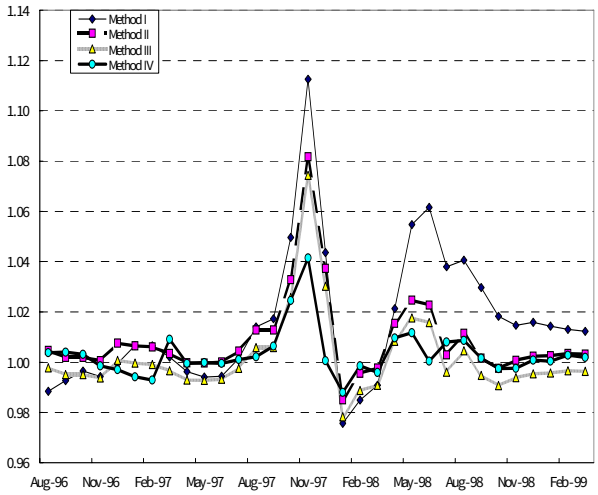
# Appendix

**<Figure A1> Sovereign Default Probability**



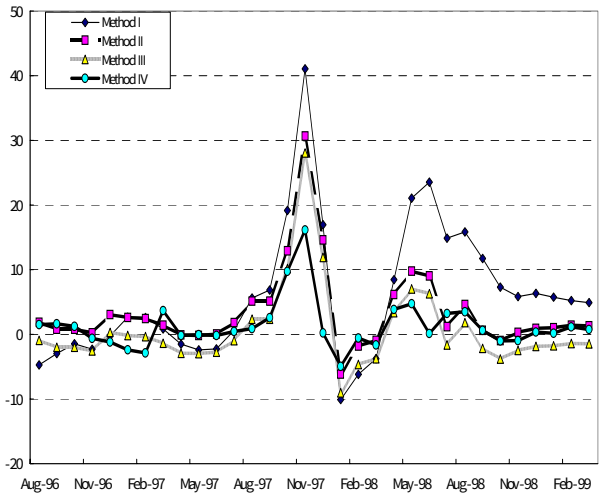

**<Figure A2> The Degree of Currency Misalignment**

(unit : %)



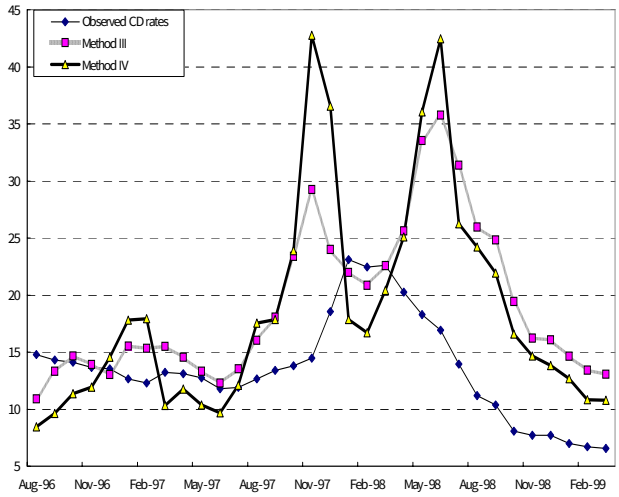

1) Salvage Value, $\chi = 0$ , is assumed.

**<Figure A3> Covered Interest Differential**

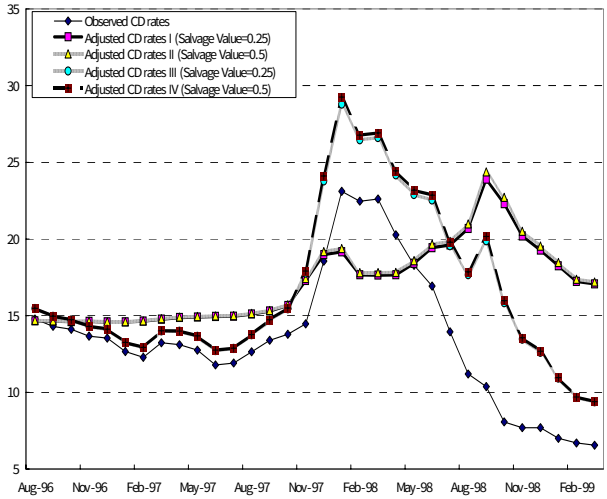



1) Salvage Value, $\chi = 0$ , is assumed.

**<Figure A4> Observed and Implied Domestic Interest Rates** (unit : %)




**<Figure A5> Observed and Risk Adjusted Domestic Interest Rates** (unit :%)




1) Salvage Value, $\chi = 0$ , is assumed.