Do high interest rates appreciate exchange rates during crisis? The Korean evidence†

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'If we raise interest rates too high, we will destroy the Korean economy.'
The IMF Director of the Asia-Pacific Department, Hubert Neiss, to IMF staff assembled to design the Korean bailout package, in Seoul Hilton, November 30, 1997.
You are destroying our economy.'
The Vice-Minister of the Ministry of Finance and Economy, Lee, to IMF staff assembled in his office in Kwachon, Korea during the Third Review of the IMF Standby, July 11, 1998.

I. Introduction

For the countries most affected by the Asia crisis, Thailand, Indonesia, and Korea, economic events have been dramatic, and have defied expectations. Exchange rates that had enjoyed a sustained period of stability depreciated precipitously. Between June 1997 and July 1998, nominal exchange rates vis-a-vis the U.S. dollar in Thailand, Indonesia, and Korea depreciated by about 67 percent, 500 percent, and 88 percent, respectively.

In response to these massive depreciations and as a condition for its adjustment lending, the IMF has required the countries to adopt tight monetary policies, specifically, to raise their short-term interest rates. After the implementation of the IMF adjustment programs, the overnight call rates

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were raised from 15 percent to 22 percent in Thailand; from 10 percent to 47 percent in Indonesia; and from 15 percent to 32 percent in Korea.

This paper tries to answer the following basic question: Have the high interest rates had the desired effect of appreciating the nominal exchange rates in the crisis countries? It is well-known that in general, there is no stable empirical short-run relationship between exchange rates and interest rates (Frankel and Rose, 1995). Nominal exchange rates move as if they are a random walk (Meese and Rogoff, 1983). However, many policy-makers believe and anecdotal evidence suggests that historically high interest rates have succeeded in stabilizing nominal exchange rates in some crisis countries, especially in Latin America.[1]

During the recent Asian crisis, the relationship between exchange rates and interest rates has again been a topic of substantial controversy. The traditional view stresses that tight monetary policies are necessary to support the exchange rate: higher interest rates raises the return that an investor obtains from investing in the country, reduces capital flight, and discourages speculation. However, several prominent economists have argued a revisionist view that a rise in interest rates has a negative effect on the exchange rate Radelet and Sachs, 1998; Feldstein, 1998; Furman and Stiglitz, 1998).

The revisionist view is that under the unique conditions of a financial panic, tight monetary policies and high interest rates would result in capital outflows and exchange rate depreciation. That is, the high interest rates cause a financial implosion, and raise default probabilities, thus weakening the currency. Radelet and Sachs (1998, pg. 31) express this view strongly:

> . . . It is entirely possible that in the unique conditions of the midst of a financial panic, raising interest rates could have the perverse effect of weakening the currency. . . Creditors understood that highly leveraged borrowers could quickly be pushed to insolvency as a result of several months of high interest rates. Moreover, many kinds of interest-sensitive market participants, such as bond traders, are simply not active in Asia's limited financial markets. The key participants were the existing holders of short term debt, and the important question was whether they would or not roll over their claims. High interest rates did not feed directly into these existing claims (which were generally floating interest rate notes based on a fixed premium over LIBOR). It is possible, however, that by undermining the profitability of their corporate customer, higher interest rates discouraged foreign investors from rolling over their loans.

While most of the work examining the relationship between tight mone-

[1] See the case studies in Goldfajn and Baig (1998) and Furman and Stiglitz (1998).

tary policies and exchange rates for the Asian crisis countries have been anecdotal, there have been recent papers that have empirically estimated the relationship. Goldfajn and Baig (1998), Kaminsky and Schmukler (1998), and Ghosh and Phillips (1998) use daily nominal interest rate and exchange rate data to attempt to calculate impulse response functions. Generally, they are unable to find statistically significant coefficients in their vector autoregressive models (VAR). Goldfajn and Gupta (1998) and Furman and Stiglitz (1998) examine episodes of currency crises using cross-country data. The results are mixed. While Goldfajn and Gupta's find that high interest rates appreciate the nominal exchange rate, Furman and Stiglitz show that if the sample is restricted to low inflation countries-which includes East Asia – high interest rates lead to exchange rate depreciations.

In this paper, we use Korean high-frequency (weekly) data during the crisis and its aftermath to examine the relationship between an increase in interest rates and the behaviour of exchange rates. We focus on Korea because of the availability of data, and because the increase in interest rates can be associated more clearly with a tightening of monetary policy.[2] We find that the lead-lag relation between the exchange rate and the interest rate clearly indicates that raising the interest rate has had the traditional impact of appreciating the nominal exchange rate during the crisis period.

This paper is organized as follows. In Section II, we present two simple models that capture versions of the traditional and revisionist stories. We show that tight money can appreciate or depreciate the nominal exchange rate, depending on how the tight money affects the long-run real exchange rate. To date, most renditions of the revisionist story have lacked explicit analytical frameworks, and a model, however basic, is useful to fix ideas. The revisionist model shows that for reasonable parameter values, tight money can cause an economic implosion large enough to weaken the currency. Thus, from a theoretical perspective, the revisionist idea is certainly plausible. In Section III, we describe the data and examine some charts relating nominal interest rates with nominal exchange rates, default probabilities and corporate bankruptcies. In Section IV we use Korean data during the crisis period and its aftermath to see if the tight monetary policy has appreciated or depreciated the nominal exchange rate. Instead of trying to directly estimate our model of Section II, we shall take a data based approach and focus on the robustness of the inference of the relationship between the interest rate differential and the nominal exchange rate. We find that the Korean experi-

[2] In Thailand and Indonesia short-term interest rates started to creep up before the IMF intervention. Thus, it is unclear whether the rates went up because of the tightening of policy or because of the crisis-induced disruption in short-term money markets.

ence clearly indicates that high interest rates have had the usual impact of appreciating the nominal exchange rate.

II. Theoretical Considerations

(i) The model

We adapt the 'workhorse' Dornbusch (1976) perfect foresight model, as modified by Obstfeld and Rogoff (1996, pp. 609-621). Five equations comprise the model: of the domestic and foreign interest rates, i and i^*; real money demand, $m - p$; real exchange rate, q; aggregate demand, y; and the inflation rate, $p_{t+1} - p_t$. (All variables are in logs. Variables that are marked with $a*$ are for the foreign country; those that are marked with a bar are long-run steady-state values.)

(1) Uncovered interest parity:

$$i_{t+1} = i* + e_{t+1} - e_t. \tag{1}$$

(2) Money demand:

$$m_t - p_t = -\eta i_{t+1} + \phi y_t \tag{2}$$

(3) The real exchange rate:

$$q_t = e_t + p* - p_t \tag{3}$$

(4) Aggregate demand:

$$y_t = \bar{y} + \sigma(e_t + p* - p_t - \bar{q}) \tag{4}$$

(5) The Phillips-curve:

$$p_{t+1} - p_t = \psi(y_t - \bar{y}) + e_{t+1} - e_t \tag{5}$$

In addition, short-run prices are taken as fixed. That is, if the economy is shocked at time 0,

$$\Delta p_0 = 0. \tag{6}$$

Obstfeld and Rogoff (1996, p. 617) show that these equations yield (normalizing $p^* = i^* = \bar{y} = 0$):

$$e_t = \frac{1}{(1+\eta)} \sum_{s=t}^{\infty} \left(\frac{\eta}{1+\eta} \right)^{s-t} m_s + \frac{(1-\phi\sigma)}{(1+\psi\sigma\eta)}(q_t - \bar{q}), \tag{7}$$

where $\bar{q}$ is the long-run level of the real exchange rate, consistent with full employment.

(ii) Monetary tightening — the traditional view

Suppose that the economy starts at a long-run ('steady-state') level of $\overline{m}$, and $\bar{e}=\overline{m}+\bar{q}$. At time 0, an unanticipated permanent *decrease* in the money supply to $\overline{m}'$ occurs. It can be shown that the nominal exchange rate at time 0 will be (Obstfeld and Rogoff, 1996, p. 617):

$$e_0 = \overline{m} + \bar{q} + \frac{(1 + \psi\sigma\eta)}{(\phi\sigma + \psi\sigma\eta)}(\overline{m}' - \overline{m}) < \bar{e} \tag{8}$$

That is, a fall in the supply of money will appreciate the nominal exchange rate. Given (4) and (6) y_t falls. In short, in the traditional view, monetary tightening will appreciate the nominal exchange rate.

(iii) Monetary tightening — the revisionist view

Assume now that instead of being constant, the long-run real exchange rate, $\bar{q}'$, depends negatively on the change in the nominal money supplies at time 0:

$$\bar{q}' = \bar{q} - \theta(m_0' - m_0) \tag{9}$$

Equation (9) captures the revisionist notion that tighter monetary policies during times of economic crisis raises bankruptcies, corporate defaults, and generally damages the long-run performance of the economy, if θ is positive.[3] Thus, a more depreciated real exchange rate is needed to achieve full employment.[4]

We assume that the long-run (irreversible) damage to the economy from tight money occurs entirely in the short-run, at time 0, when prices are sticky. Clearly, as prices adjust, real money supply is constant. Thus, we assume that

[3]There is a macroeconomics literature starting from Bernanke (1983) that has argued that because markets for financial claims are incomplete, intermediation between some classes of borrowers and lenders requires nontrivial market-making and information-gathering sources. Tight money can reduce the effectiveness of the financial sector as a whole in performing these services, and thus cause a credit-crunch. In fact, Bernanke (1983) has argued that such a credit-crunch helped convert the U.S. downturn of 1929-1930 into a protracted depression.

Some commentators (Furman and Stiglitz, 1998) have pointed out that during the recent Asian crisis, these depression-like phenomena have been replicated by the tight monetary policies. High interest rates compromised the net worth of many Asian firms, and the bankruptcies of these firms had adverse effects on the net worth of the firms' creditors, especially that of domestic financial institutions. In turn, as these financial institutions went bankrupt, and banks cut lending, credit became highly constrained. A credit crunch set in, exacerbating the economic downturn.

[4]Most econometric studies cannot reject the null hypothesis that the real exchange rate is a random walk, suggesting that shocks to the real exchange rate are permanent (Froot and Rogoff, 1995). In fact, Obstfeld and Rogoff (1996) offer an optimizing model in which a monetary shock leads to long-lasting changes in the real exchange rate.

the behaviour of money from time 0 onwards does not affect the long-run real exchange rate.

Since by assumption, nominal money supplies from time 1 to infinity (m_1 to m_∞) do not affect $\bar{q}'$, we can assume that the money supply changes are permanent and rewrite equation (9) as:

$$\bar{q}' = \bar{q} - \theta(\bar{m}' - \bar{m}) \tag{10}$$

Equation (8) now becomes:

$$e_0 = \bar{m} + \bar{q} - \theta(\bar{m}' - \bar{m}) + \frac{(1 + \psi\sigma\eta)}{(\phi\sigma + \psi\sigma\eta)}(\bar{m}' - \bar{m}) \tag{11}$$

For a monetary tightening to depreciate the nominal exchange rate, $e_0 > \bar{e}$,

$$\theta > \frac{(1 + \psi\sigma\eta)}{(\phi\sigma + \psi\sigma\eta)}. \tag{12}$$

Equations (11) and (12) capture the revisionist notion that if the negative impact of the nominal money tightening on the long-run real economy is high enough, then the money tightening can perversely cause the nominal exchange rate to depreciate.

Given plausible parameter values, what must θ be for (12) to be satisfied? Tseng and Corker (1991) estimate a macroeconometric model for Korea and find that, $\eta = 0.01$, $\phi = 1.0$, $\psi = 5$ and $\sigma = 1.0$. Given these estimated parameter values, the right hand side of equation (12) is equal to unity. Thus, if θ is greater than unity, the nominal exchange rate will depreciate.

Is a value of θ greater than unity plausible? Inserting equation (4) into money demand, (2), taking first differences, noting that $\Delta p_0 = 0$, and simplifying[5]

$$\Delta m_0 = -\eta\Delta i_0 + \phi(\sigma(\Delta e_0) + \sigma(\bar{q}' - \bar{q})) \tag{13}$$

Plugging in (11) for Δe_0 in (13), and (10) for $(\bar{q}' - \bar{q})$ in (13) recalling that $\Delta m_0 = \bar{m}' - \bar{m}$, and simplifying,

$$\Delta m_0 = -\frac{\eta\Delta i_0}{\left(1 + 2\theta\phi\sigma - \dfrac{(1 + \psi\sigma\eta)\phi}{(\phi + \psi\eta)}\right)} \tag{14}$$

Substituting in plausible parameter values and assuming a value of $\theta > 1$ (say $\theta = 1.5$), it can be shown that for nominal interest rates to increase from about 10 percentage points to about 40 percentage points, or 300 percent as

[5]Note that aggregate demand, y_0, after the monetary tightening becomes

$$y_0 = \bar{y} + \sigma(e_0 - \bar{q}').$$

they did in Korea in December, 1997, nominal money would need to fall by about 1 percent. Then from (9), given $\theta = 1.5$, the long-run real exchange rate should depreciate by about 1.5 percent. A fall in $\bar{q}$ of this magnitude certainly seems reasonable. For example, Goldfain and Baig (1998) show that in many Latin American countries, following a currency crisis, real exchange rate depreciations in the order of 10–15 percent were common. Thus, from a theoretical viewpoint, the revisionist position certainly seems plausible.

(iv) More general money supply processes

During the recent Asian crisis, the tightening of monetary policies were only temporary. For example, in Korea, after rising sharply in December, interest rates were steadily brought down starting in January 1998 and by August 1998, rates were even lower than in October 1997, before the crisis.

The revisionist case can be justified under more general money supply processes, including one in which money supply sharply contracts, and then gradually loosens—as in Korea. Assume as above that there is long-term damage to the economy when money is tightened sharply. This damage is not reversed when money supply is subsequently relaxed. Assume that after contracting at time 0, the money supply process returns to its old path. Since the model is linear in m_s (equation 7), the nominal exchange rates under the traditional (e_0) and revisionist (e_0^R) cases differ only by $-\theta(m_0' - m_0)$ (given equation (9)). Thus, e_0^R will always be more depreciated than e_0. In fact, for a large enough θ, a fall in m_0 can cause e_0^R and e_0 to move in opposite directions; e_0^R can depreciate.

III. The Data and Charts

For Korea, we have obtained data on both forward and spot exchange rates; various interest rates; and corporate bankruptcies from September 1997 to August 1998. We have also obtained data on interest rates for the United States. The data on spot exchange rates and interest rates are from the Bloomberg terminal. The data on forward exchange rates, and corporate bankruptcies are from the Bank of Korea.[6] We perform our analysis at the weekly frequency, by using observations for each Wednesday.

For the Bank of Korea, the main monetary instrument is the overnight call rate. Chart 1 depicts the relationship between the overnight call rate and the differential between the Korean 3-month CD rate and the U.S. 3-month Treasury bond rate.[7] The call rate and interest rate differentials move closely

[6]Forward rates are non-deliverable and are quoted in Singapore.

[7]Since the Korean government has guaranteed the liabilities of Korean banks, the CDs are essentially sovereign debt. Since the mid-1990s, foreigners were able to hold these CDs.

together. After the announcement of the Stand-by agreement with the IMF on the week of December 8, the call rate was increased from about 12 percent to 24 percent. An agreement was reached between the Korean authorities and the IMF that the call rate will be increased and will be kept high as long as the exchange rate remained at a depreciated level.[8] In the following week, however, the won depreciated further, and the call rate was raised again during the week of December 22 to over 32 percent. Over the following months, as the won appreciated, the call rate was gradually lowered, and by early August, was even below pre-crisis levels.

Given that the call rate and interest rate differentials move closely together and that interest parity conditions relate exchange rates to interest rate differentials, we conduct our econometric analysis using interest rate differential data. Chart 2 depicts the relationship between interest rate differentials and the spot and forward won/dollar rates. Both the spot and forward exchange rates started to depreciate during the week of October 20 and the rates of depreciation accelerated during the week of November 17. The won reached its low point during the week of December 1, and while it briefly appreciated, reached another low point during the week of December 22. It was only in late February 1998, when the won started to steadily appreciate. The volatility of exchange rates was also high between late November and late February (Chart 3).[9]

The revisionist view on the impact of high interest rates on exchange rates hinges on how interest rates impact bankruptcies and therefore default probabilities. Chart 4 shows the relationship between higher interest rates and bankruptcies.[10] Chart 5 depicts the relationship between interest differentials and default premia, defined as the interest differential minus the forward premium.[11] The default premia (S) started to rise during the week of November 3, peaking during the week of December 3, as interest rates peaked. Thereafter, the default premia declined, following the downward trend in interest rates. Default premia can also be calculated as the difference between the interest rates of U.S. bonds and dollar denominated Korean bonds. Chart 6 depicts the behaviour in the long-term bond default premium (L), calculated as the difference between the U.S. 10-year treasury bill and the 10-year Korea Export-Import Bank (KExim) dollar denominated offshore

[8] An understanding was reached between both parties that a won/dollar exchange rate above 1500 was too weak (depreciated). The understanding was that as long as the won remained below 1500, the call rate could gradually be brought down.

[9] Weekly volatilities are calculated as the standard deviation of the daily spot exchange rates.

[10] Corporate bankruptcies in the Seoul area.

[11] For countries with open capital markets and liquid foreign exchange markets, given covered interest parity, banks simply calculate the forward premium from the difference in interest rates. However, given the existence of various capital restrictions in Korea, covered interest parity may not exactly hold, and the won/dollar forward premia that is quoted in Singapore is market determined.

bond.[12] The default premia on KExim bonds started to rise during the week of October 20, and peaked during the week of December 22, but subsiding thereafter.

The positive relationship, however, between the interest differential, and the default premia shown above does not prove the revisionist position. For

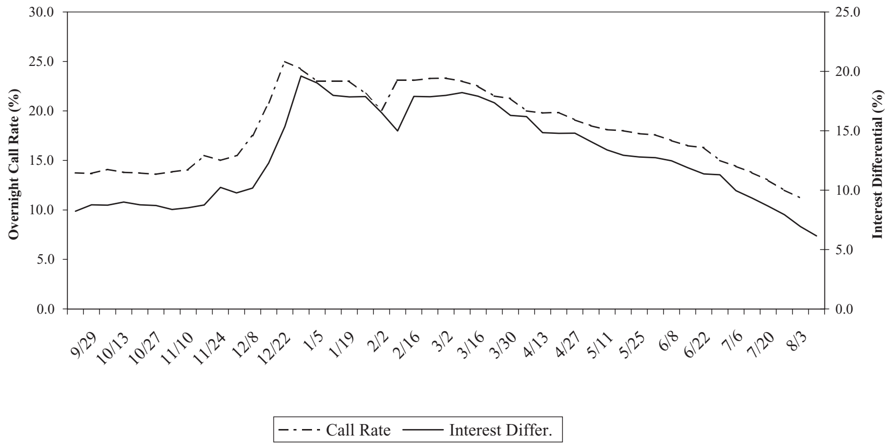

Chart 1. Call Rate and Interest Differentials

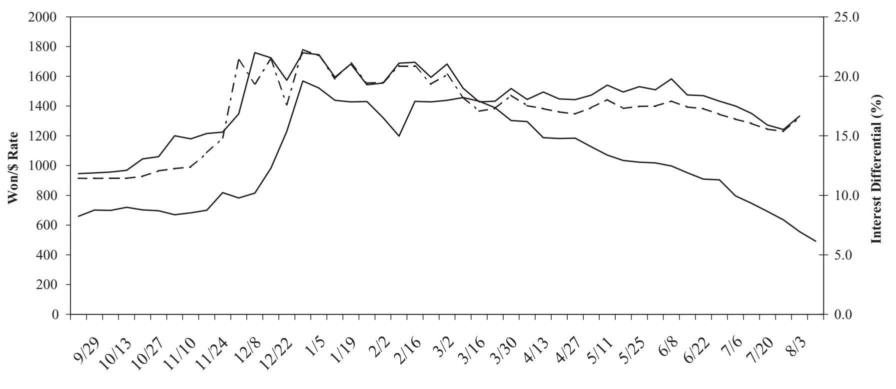

Chart 2. Exchange Rates and Interest Differential

[12]The KExim is a government-owned bank, and therefore its liabilities are sovereign.

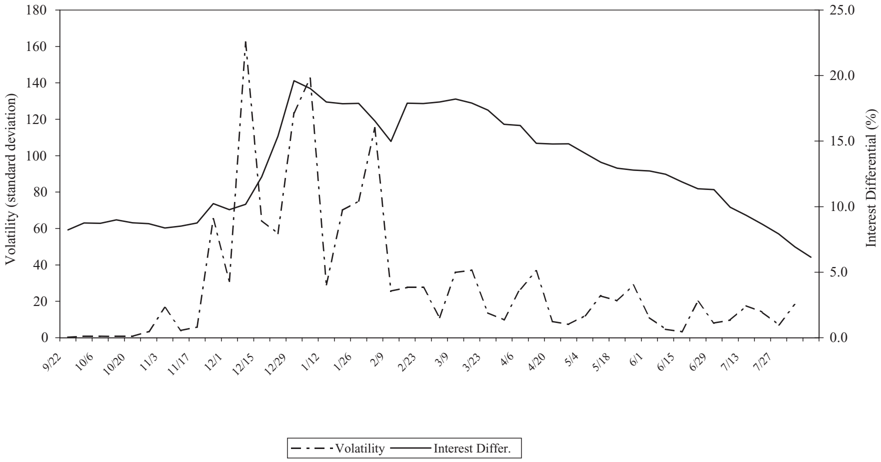

Chart 3. Volatility and Interest Differentials

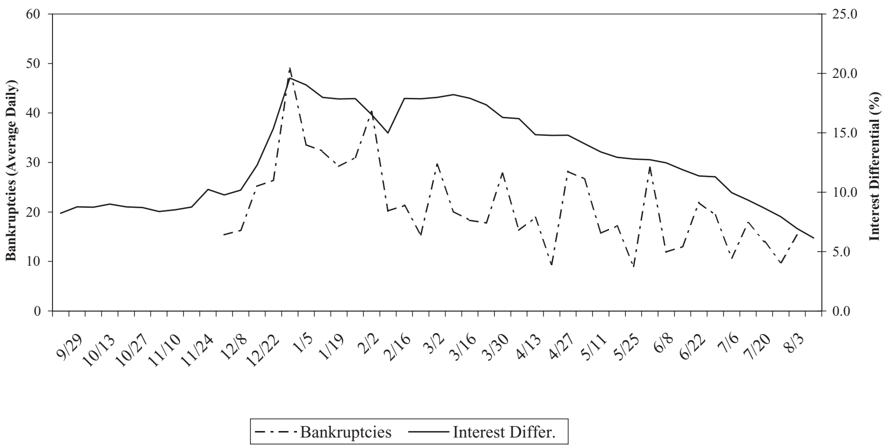

Chart 4. Bankruptcies and Interest Rates

example, default premia can rise due to heightened risk that is reflected in higher exchange rate volatilities. In fact, the rise in the default premia during late October and early November presages the rise in interest rates (Chart 6). The authorities may be responding to these exchange rate risks by raising interest rates, and thus the correlation between default premia and interest rates could be spurious.

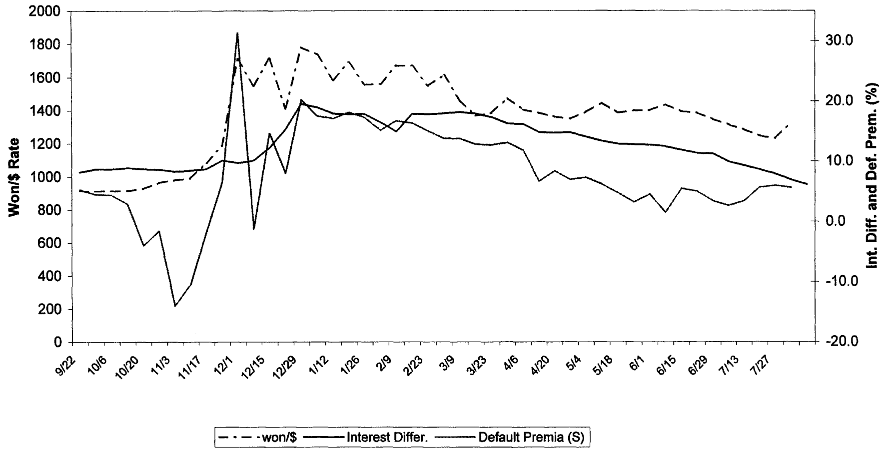

Chart 5. Interest Differentials and Default Premia (S)

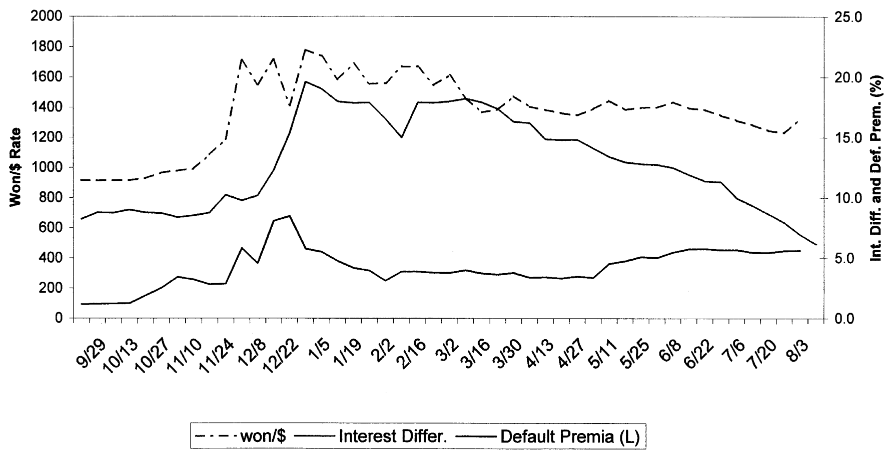

Chart 6. Interest Differentials and Default Premia (L)

IV. Empirical Results

Because of the controversy surrounding the role of tight monetary policies and high interest rates in stabilizing the exchange rate, in this section, we hope to shed light on this dispute by examining some Korean high frequency financial market data during the crisis. We examine the Korean weekly spot exchange rate, the Korean and U.S. interest rate differential, and the Korean corporate bankruptcy rate from September 1997 to August 1998. We focus on this period because of the availability of data and because the Korean monetary policy regime can most clearly be identified with stabilizing the exchange rate. Including later or earlier time periods may result in mixing different monetary policy regimes. For example, since mid-summer 1998 the IMF has allowed the Bank of Korean to lower interest rates to stimulate domestic activity. Although as mentioned, the main monetary control variable of the Bank of Korea is the overnight call rate, we use the differential between the 3-month CD rate and the U.S. T-bill rate. We feel that the differential captures more of the market's expectation of the relative returns to Korean and U.S. currencies.

Although the model presented in section II is suggestive, it does not begin to cover the financial panic type of phenomena described by Radelet and Sachs (1998, p. 31). Moreover, the assumption that monetary tightening has a permanent affect on the real exchange rate is controversial. Given that the right model for the Asian crisis is unknown, structural estimation can lead to biased estimates. Therefore, instead of estimating model-based parameters, we take the approach of letting the data speak for themselves. In fact, in one of our specifications, we adopt the restriction of long-run Purchasing Power Parity, implying a steady long-run real exchange rate.

The advantage of our vector autoregressive time series approach is that it is an unrestricted reduced form specification, and thus avoids the possibility of misleading inference due to incorrect model specification. In fact, the same reduced form can correspond to different structural models with the proper imposition of *a priori* restrictions (e.g. Hsiao (1983, 1997, 2000), Hsiao and Fujiki (1998)). The disadvantage of a time series specification is that it usually involves a large number of parameters.[13] This makes the selection of an appropriate time series specification difficult, because the distribution theory on which tests are based is asymptotic. For many of the hypothesis tested, the degrees of freedom of the test statistics are of the same magnitude as the degrees of freedom left in the data after fitting the model.

To partially alleviate the problems associated with estimating a profligately specified time series model, we shall combine the notion of Granger (1969) causality and cointegration (Engle and Granger (1987)) to reduce the number of parameters estimated and get around the issue of nonstandard test statistics with the presence of integrated variables. In addition, we also consider the inter-relationships between our time series model and some simple structural models (such as Purchasing Power Parity) by placing the restrictions implied by the structural models on the corresponding time series

[13] For an unrestricted vector autoregressive model involving four variables with the order of lag equal to 5, we will have to estimate 80 coefficients and 10 variance-covariances. The shortages of degrees of freedom and multicollinearity can yield a large number of statistically insignificant coefficient estimates. This empirical phenomenon makes the interpretation of the test difficult.

model. Our goal is to obtain robust inferences of the relationship between the exchange rate and the interest rate differential.

We take the following steps to fit the time series models:

First, because estimates based on stationary and nonstationary data have very different limiting distributions (e.g. Anderson (1971), Johanson (1988, 91), Phillips (1986, 87, 91, 98)), we test for the presence of unit roots in the logarithmic transformation of the spot exchange rate, s_t, interest rate differential, i_t, and inflation rate differential, p_t. We use the Schwarz (1978) criteria to choose the optimal order of lags to conduct the ADF test (Dickey and Fuller (1979)). Table 1 gives the ADF test statistics for the level and the first difference of the logarithmic transformation of exchange rate, s_t, interest rate differential i_t, inflation-rate differential p_t, and bankruptcy rate p_t.[14] These results indicate that we should treat all these variables as integrated of order 1, I(1), process.

Second, because the results of hypotheses testing are very sensitive to the order of the autoregressive process (e.g. Hsiao (1979a, 82a,b)), we use the Akaike (1973) criterion to determine the order of the vector autoregressive process. Since we have only a limited number of observations, a priori we specify the highest order of lag to be five. The Akaike criterion selects the optimal order of lag to be 3.

Third, we test for the rank of cointegration using the Johanson likelihood ratio test. The likelihood ratio test statistics of rank 0 against rank 1 based on the maximum eigenvalue of the stochastic matrix is 26.07. The 95 percent critical value is 28.27. The likelihood ratio test statistic based on the trace of the stochastic matrix is 55.53. The 95 percent critical value is 53.48. The test statistic between rank 1 and 2 is 29.46. The 95 percent critical value is 34.87. From these results, it appears that either these four variables are not cointegrated or are cointegrated with rank 1.

Fourth, under the assumption that the cointegrating rank is 1, we apply the Johanson (1988) maximum likelihood method to estimate to the following model

$$\Delta \underset{\sim}{w}_t = \pi_1 \Delta \underset{\sim}{w}_{t-1} + \pi_2 \Delta \underset{\sim}{w}_{t-2} + \underset{\sim}{\alpha} \underset{\sim}{\beta}' \underset{\sim}{w}_{t-1} + \underset{\sim}{\eta}_t, \tag{15}$$

where $w_t = (s_t, i_t, p_t, p_t)$, $\Delta = (1 - L)$ and L denotes the lag operator, $\underset{\sim}{\alpha}$ and β are 4×1 vectors denoting the short run response coefficient from the deviation of the long-run equilibrium and long-run equilibrium relation respectively. The estimates are reported in Table 2.

[14]The tests of s_t, i_t, and p_t are based on observations from September 1997 to the first week of 1998. The tests b_t are based on observations from September 1997 to August 1998. However, because of the unavailability of b_t after August 1998, we fit our time series models only using data from September 1997 to August 1998.

Fifth, because the estimated long-run relation takes the form

$$s_t = 4.9098 - 0.43718 i_t + 6.3586 p_t - 0.47924 p_t \tag{16}$$

which is hard to give a meaningful economic interpretation, we impose the long-run purchasing power parity relation by specifying $\tilde{\beta}' = (1, 0, -1, 0)$ and re-estimate model equation (15).[15] The results are presented in Table 3.

Sixth, under the assumption that there is no cointegrating relation among these four variables, we take the first difference to transform the data into stationarity. We then use Hsiao's (1979a,b) method to select a parsimonious vector autoregressive specification that allows each variable to enter into each equation with different order of lags. The seemingly unrelated regression estimates of the final specification are reported in Table 4.

Seventh, we split up the sample period into two. The first period consists of observations from 1 to 41. The second period consists of the last seven observations. We use the first period data to reestimate models 1, 2, and 3,

TABLE 1
Unit Root Tests

Variables	*AIC (P)*	*SBC (P)*	*95% Critical Values*
S (Spot Exchange Rate)	−2.8049 (2)	−2.8049 (2)	−2.9092
I (Interest Rate Differential)	−0.27416 (1)	−0.66765 (0)	−2.9092
P (Inflation Rate Differential)	−3.5329 (3)	−3.3765 (2)	−2.9101
B (Korean Corporate Bankruptcy Rate)	−2.3928 (1)	−4.0892 (0)	−2.9378
Δ S	−3.3712 (1)	−3.3712 (1)	−2.9101
Δ I	−9.3917 (0)	−9.3917 (0)	−2.9101
Δ P	−2.3779 (4)	−2.9710 (0)	−2.9109
Δ B	−6.6124 (1)	−10.6222 (0)	−2.9400

AIC = Akaike Information Criterion
SBC = Schwarz Bayesian Criterion
Note:
1. P give the order of lags selected by the AIC or SBC.
2. Test statistics for variables S, ΔS, I and ΔI are based on 67 observations from September 19, 1997 to December 19, 1998.
   Test statistics for variables P and ΔP are based on 66 observations from September 19, 1997 to December 19, 1998.
   Test statistics for variables B and ΔB are based on 48 observations from September 19, 1997 to July 19, 1998.

[15] It should be noted that the imposition of long-run purchasing power parity contradicts our presentation of the revisionist view as expressed by (10).

TABLE 2

Parameter Estimates of Model 1, with One Estimated Long-run Relation

	ΔS	ΔI	ΔP	ΔB
ΔS (−1)	0.10100	0.0990965	0.029160	−1.9439
	(0.55455)	(0.48780)	(2.0476)	(−1.8687)
ΔS (−2)	0.54026	0.59879	0.026589	−0.39569
	(3.7391)	(3.7166)	(2.3535)	(−0.48057)
ΔI (−1)	−0.25088	−0.063581	−0.0028158	−0.78358
	(−1.6257)	(−0.36950)	(−0.23336)	(−0.88902)
ΔI (−2)	0.12963	−0.32097	0.017012	−0.57249
	(0.90212)	(−2.0032)	(1.5141)	(−0.69753)
ΔP (−1)	3.5465	4.0623	0.066447	10.8913
	(1.8240)	(1.8738)	(0.47084)	(0.98076)
ΔP (−2)	0.92440	−1.7923	0.16615	25.4201
	(0.45447)	(−0.79027)	(1.0447)	(2.1882)
ΔB (−1)	0.0049843	0.064777	−0.0023211	0.33603
	(0.10556)	(1.2304)	(−0.62872)	(1.2461)
ΔB (−2)	−0.0051318	0.041174	−0.6528E-3	0.25162
	(−0.16451)	(1.1837)	(−0.26763)	(1.4122)
V* (−1)	0.061562	−0.047836	0.0074383	−1.3923
	(1.1853)	(−0.82600)	(1.8316)	(−4.6936)

*: Cointegrating Vector
$V = -2.3731\ S - 1.0375\ I + 15.0899\ P + 1.1373\ B + 11.6$

TABLE 3

Parameter Estimates of Model 2, Assuming Long-run Purchasing Power Parity

	ΔS	ΔI	ΔP	ΔB
ΔS (−1)	−0.0074633	0.19838	0.014933	0.60463
	(−0.046904)	(1.1527)	(1.1815)	(0.52586)
ΔS (−2)	0.50042	0.64976	0.020283	0.63156
	(3.5033)	(4.2056)	(1.7876)	(0.61187)
ΔI (−1)	−0.33460	0.10248	−0.010981	0.94379
	(−2.3359)	(0.66147)	(−0.96511)	(0.91183)
ΔI (−2)	0.86411	−0.29444	0.012315	0.36033
	(0.60817)	(−1.9160)	(1.0912)	(0.35097)
ΔP (−1)	4.4248	3.7977	0.14141	−6.3199
	(2.3518)	(1.8662)	(0.94623)	(−0.46486)
ΔP (−2)	−0.21171	−1.7912	0.21088	12.8233
	(−0.10375)	(−0.81160)	(1.3011)	(0.86969)
ΔB (−1)	0.044190	0.029277	0.0034184	−0.75890
	(1.8450)	(1.1302)	(1.7968)	(−4.3850)
ΔB (−2)	0.019344	0.025969	0.0020202	−0.27774
	(0.78744)	(0.97737)	(1.0353)	(−1.5646)
U* (−1)	−0.4265E-3	−0.0016203	0.9401E-4	−0.0027402
	(0.34385)	(−1.2078)	(0.95424)	(−0.30574)

*: Imposed Purchasing Power Parity Condition: $U = S - P$

TABLE 4
Parameter Estimates of Model 3, Assuming No Cointegration Relation

	ΔS	ΔI	ΔP	ΔB
Intercept	−0.00598039	−0.011827	0.00030641	−0.037891
	(−0.68)	(−1.29)	(0.90)	(−0.67)
ΔS (−1)	−0.047141	0.153907		0.487702
	(−0.34)	(0.96)		(0.49)
ΔS (−2)	0.559816	0.641913		1.73203
	(4.34)	(4.70)		(2.03)
ΔS (−3)		0.311306		1.993429
		(1.96)		(1.95)
ΔI (−1)	−0.286235			
	(−2.27)			
ΔI (−2)				
ΔI (−3)				
ΔP (−1)	6.428625		0.801466	
	(2.54)		(8.47)	
ΔP (−2)				
ΔP (−3)				
ΔB (−1)				−0.831877
				(−5.29)
ΔB (−2)				−0.551550
				(−3.01)
ΔB (−3)				−0.301370
				(−1.95)

then use the estimated coefficients and first period data to generate predicted values for the last seven observations.

Table 5 presents the prediction root mean square error of the changes and the levels of the spot exchange rate, interest rate differential, inflation rate differential, and the bankruptcy rate. It is interesting to note that apart from the changes in the bankruptcy rate, the time series model imposing the long-run purchasing power parity restriction (model 2) actually predicts better than the unrestricted time series model with our estimated cointegration relation (model 1). The model without cointegration (model 3) predicts worse than model 2, but better than model 1 with regard to *changes* in the spot exchange rate, interest rate differential, inflation rate differential, and the *levels* of the inflation rate differential and the bankruptcy rate, but worse in predicting the *levels* of the spot rate, interest rate differential, and the *changes* in the bankruptcy rate. Thus, using the prediction error as a criterion, the results strongly point in favor of the time series model with the imposition of the *a priori* long-run purchasing power parity relation, over the unrestricted time series model with the cointegration relation, or the model without cointegration.

Comparing the results in Tables 2, 3 and 4 we note that there is a feedback relation between the exchange rate and the interest rate. That is, there is a causal relation not only from the interest rate to the exchange rate, but also from the exchange rate to the interest rate. Neither the exchange rate, nor the interest rate can be treated as strictly exogenous.[16] The results suggest that at the time of the crisis, interest rates rise until the currency stops depreciating, and then as the crisis recedes, the interest rate comes down. However, the results also suggest that the rise in the interest rate differential has the traditional impact of appreciating the nominal exchange rate, and this relation is surprisingly robust.

Moreover, the VAR model subject to the restriction of long-term purchasing power parity (PPP) appears to perform best empirically. This restriction contradicts our presentation of the revisionist view as expressed by (10) because the real exchange rate is always $\bar{q}_t = e_t \cdot (P_t^*)/P_t = 1$ under PPP. That the VAR with the PPP restriction performs best strengthens our conclusion that there is no evidence supporting the revisionist view that a rise in the interest rate has a negative effect on the exchange rate.

The exchange rate equation under the assumption of no cointegrating relation is

$$\Delta s_t = \underset{(-0.68)}{0.00598} - \underset{(-0.34)}{0.0471}\Delta s_{t-1} + \underset{(4.34)}{0.5598}\Delta s_{t-2} - \underset{(-2.27)}{0.286}\Delta i_{t-1} + \underset{(2.54)}{6.4286}\Delta p_{t-1} + \hat{\eta}_t \tag{17}$$

with the long-run purchasing power parity imposed is

$$\begin{aligned}\Delta s_t = & -\underset{(-0.047)}{0.0075}\Delta s_{t-1} + \underset{(3.50)}{0.50}\Delta s_{t-2} - \underset{(-2.34)}{0.3346}\Delta i_{t-1} + \underset{(0.61)}{0.0864}\Delta i_{t-2} \\ & + \underset{(2.35)}{0.4248}\Delta p_{t-1} - \underset{(-0.10)}{0.2117}\Delta p_{t-2} + \underset{(1.85)}{0.0442}\Delta b_{t-1} + \underset{(0.79)}{0.0193}\Delta b_{t-2} \\ & - \underset{(0.34)}{0.00042}v_{t-1}\end{aligned} \tag{18}$$

[16]It should be noted that the concept of Granger causality is different from the concept of exogeneity. There may be causal relations between variables without the existence of exogeneity as the presence of feedback relation between interest rate and exchange rate.

and with the estimated cointegrating relation is

$$\Delta s_t = \underset{(0.55)}{0.101\Delta s_{t-1}} + \underset{(3.74)}{0.540\Delta s_{t-2}} - \underset{(-1.63)}{0.251\Delta i_{t-1}} + \underset{(0.90)}{0.130\Delta i_{t-2}}$$

$$+ \underset{(1.82)}{3.5465\Delta p_{t-1}} + \underset{(0.45)}{0.924\Delta p_{t-2}} + \underset{(0.11)}{0.00498\Delta b_{t-1}} - \underset{(-0.16)}{0.00513\Delta b_{t-2}}$$

$$+ \underset{(1.19)}{0.616\hat{v}_{t-1}}, \qquad (19)$$

where the t-statistics are in parenthesis and $v_t = s_t - p_t$, $\hat{v}_t = -2.37s_t - 1.04i_t + 15.1p_t + 1.14p_t + 11.6$.

Impulse response functions were calculated assuming a Wold ordering of $\{i_t, s_t, p_t, b_t\}$. Among other things, this corresponds to the assumption that the Bank of Korea looks at only the lagged values of s_t, p_t, b_t when setting its interest rate policy. In turn, s_t, p_t, and b_t are affected by the contemporaneous value of i_t. However, we found that our results were very robust to adopting different recursive orderings.

Chart 7 plots the impulse response functions of a one standard error shock to the interest rate differential on the exchange rate. Again, the three different time series models have remarkably similar effects. However, the chain of events of the interest differential shock under these three specifications are different. In (17), a shock to the interest rate differential creates a shock to the exchange rate. However, because the exchange rate follows a random walk, the effects of the shock never dies out. On the other hand, equations (18) and (19) imply that the impact of the interest differential shock also depends on the shock's impact on the inflation rate and on the bankruptcy rate through the long-run relations $s_t = p_t$ or $s_t = 4.91 - 0.437i_t + 6.357p_t - 0.479b_t$. Equations (17)–(19) show that the short-run elasticity of the exchange rate to the interest rate differential is in the range of -0.25 to -0.3. The impulse response functions indicate that the eventual impact of a 100 percent basis point increase of the interest rate to the exchange rate after 40 weeks is in the range of -0.21 to -0.26. In other words, although we have not found evidence to support the revisionist view, the use of high interest rates to defend nominal exchange rate is probably not very effective. To defend a 40 percent depreciation of the nominal exchange rate, the interest rate differential will have to be raised by about 200 percent.

The bankruptcy rate also appears to respond positively to the nominal exchange rate. However, we are not able to find any direct link between the bankruptcy rate and the interest rate differential in the short-run. This is perhaps due to the short-time period used, or perhaps because the interest rate is reacting to the exchange rate depreciation and the impact of the rising

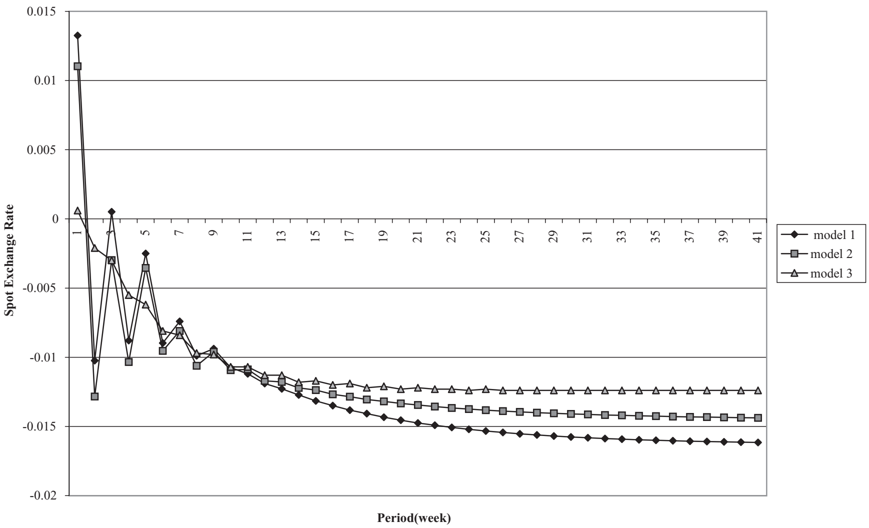

Chart 7. Impulse Responses to One Standard Error Shock to Interest Rate Differential

TABLE 5
H-Period Ahead Root Mean Square Error Comparison

	Model 1	*Model 2*	*Model 3*
ΔS	0.032996	0.027577	0.029980
ΔI	0.051052	0.048289	0.048608
ΔP	0.0058651	0.0044566	0.00055145
ΔB	0.54950	0.44197	0.59747
S	0.067431	0.038322	0.098138
I	0.15316	0.14752	0.16349
P	0.023052	0.013003	0.00078863
B	0.40638	0.29109	0.38951

interest rate has already been picked up by the exchange rate depreciation. These results are consistent with the traditional view that high bankruptcies are caused not by high interest rates, but by the depreciated exchange rate, which raises debt burdens in domestic currency terms.

V. Conclusions

In this paper we have presented two views on the impact of tight monetary policies on nominal exchange rates during times of economic crisis. The empirical results are supportive of the traditional view. Monetary tightening and the rise in interest rates appear to have succeeded in appreciating the Korean won. Given the limited number of observations and noise in the data, the time series specifications can be fragile. However, we found that the relationship between the exchange rate and the interest rate differential is surprisingly robust to different specifications. As Leamer and Leonard (1983) remarked: 'Researchers (are) given the task of identifying interesting families of alternative models and (are) expected to summarize the range of inferences which are implied by each of the families. When a range of inference is small enough to be useful and when the corresponding family of models is broad enough to be believable, we may conclude that these data yield useful information. When the range of inferences is too wide to be useful, and when the corresponding family of models is so narrow that it cannot credibly be reduced, then we must conclude that inferences from these data are too fragile to be useful'.

Thus, we conclude that the Korean experience supports the traditional view that raising the interest rate does appreciate the nominal exchange rate. Furthermore, we find that the corporate bankruptcy rate responds more to the exchange rate depreciation than to the interest rate increase. In short, we have not found evidence supporting the revisionist view that high interest rates result in rising corporate bankruptcies, capital outflows, and hence, depreciating exchange rates.

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