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New Evidence on High Interest Rate Policy During the Korean Crisis

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ABSTRACT

This paper evaluates the effectiveness of the high interest rate policy in stabilizing the exchange rate during the Korean crisis, based on a nonlinear impulse response function approach. By tracing impulse responses within an estimated model, we find that high interest rates induce depreciation for a very short period (five days), followed by a substantial appreciation for an extensive period (more than three months). In contrast, a low interest rate policy would appreciate the exchange rate only for a very short period but have little impact afterwards, indicating an asymmetry in the exchange rate response to an interest rate shock. The impulse function analysis also suggests that a cutback of interest rates to the pre-crisis level does not cause serious depreciation. Our findings suggest that the IMF's interest rate policy in Korea, which was characterized by a sharp increase in interest rates at the onset of the crisis followed by a cutback after several months, contributed to the stabilization of the exchange rate.

1. Introduction

When Korea was hit hard by the financial crisis in 1997, the IMF rescue program

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included a high interest rate policy for more than three months to stabilize the won/dollar exchange rate. The short-term inter-bank interest rate was raised to 30 percent on December 26, 1997 in response to the exchange rate plummeting from 900 to 2,000 Korean won against the U.S. dollar. As the exchange rate stabilized, the short-term interest rate started to ease following an agreement between the Korean government and the IMF on February 7, 1998. Thereafter the interest rate was gradually lowered as the situation in the foreign exchange market improved. The interest rate fell below its pre-crisis level in the middle of 1998, and has remained low since then.

The high interest rate policy recommended by the IMF for the crisis-hit Asian countries has generated immense public and academic debates. Proponents of the policy such as Fischer (1998) suggest that the high interest rate policy helped stabilize exchange rates during the crisis. By restoring confidence and fostering needed corporate restructuring, the policy encouraged capital inflow to, or discouraged capital outflow from, countries in crisis, which subsequently strengthened their currencies. Opponents of the policy such as Furman and Stiglitz (1998) argue that the high interest rate policy destabilized exchange rates by raising corporate bankruptcies, which accelerated capital outflows.

The debate also stimulated an emerging literature seeking to empirically evaluate the efficacy of the high interest rate policy. The empirical evidence so far is mixed.[1] Some recent studies find that the high interest rate policy helped to stabilize exchange rates. For example, Dekle, Hsiao, and Wang (1998), using weekly Korean data, find that raising interest rates contributed to appreciation during the crisis period. Goldfajn and Gupta (1999), using monthly data for 80 countries for 1980-98, find evidence that high interest rates helped to stabilize exchange rates (see also Cho and West, 2001). On the other hand, Furman and Stiglitz (1998), using data for nine developing countries, suggest that high interest rates had a negative or little effect on foreign exchange stability. Goldfajn and Baig (1998), based on VAR analysis using daily data for crisis-hit Asian countries, find a positive correlation between real interest rates and exchange rates for Hong Kong, Indonesia and Malaysia, but a negative correlation for Korea and Thailand.

Surprisingly, the existing empirical studies yield a mixed result for Korea. The reason for the seemingly inconsistent results from previous studies may be because they do not allow for a nonlinear relationship between interest rates and foreign exchange

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expressed herein are those of the authors and not necessarily of the IMF or the KIEP.

[1] There are also a few recent theoretical papers, including Lahiri and Végh (2000) and Flood and Jeanne (2000).

rates. The purpose of this paper is to evaluate the high interest rate policy during the Korean crisis with a focus on nonlinear effects, in sharp contrast to previous studies. It is important to allow for nonlinearities for the following reasons.

First and most obviously, the relationship between interest rates and exchange rates may, in fact, have significant nonlinear characteristics (Bansal, 1997; Lahiri and Végh, 1999; and Chung, 1998). For example, exchange rate movements may depend on whether the interest rate differential between two countries is large or small.

Second, there may be rich nonlinear dynamics in the time path of exchange rate responses to interest rate shocks stemming from the fact that the relationship between interest rates and exchange rates is affected by a number of other variables, including capital inflows and outflows, corporate bankruptcies, the current account balance, policy credibility, and risk premiums.

Third, the nonlinear model can facilitate the empirical analysis of whether a rise in interest rates has different effects than a fall, something that previous studies have not addressed. The examination of the asymmetric effects is important, particularly because the IMF's high interest rate policy had two phases: a rise in interest rates in the initial period followed by a cutback.

To take nonlinearities into account, we use semi-nonparametric (SNP) estimation, a nonlinear econometric methodology developed by Gallant and Tauchen (1989), followed by nonlinear impulse response analysis developed by Gallant, Rossi, and Tauchen (1993). By applying this methodology to Korean daily data, we compare the reactions of the conditional means of exchange rate changes to various interest rate shocks without relying on a specific parameterization of the mean and variance equations. Intuitively, the methodology can be regarded as an extension of linear impulse response function in VAR analysis to the nonlinear model. By analyzing nonlinearities, however, this model is able to detect potential asymmetries in the response of exchange rates to different types of interest rate shocks. It can also trace out the dynamic path of the exchange rate response, thereby providing a basis for assessing the short- and long-term effect of interest rate changes on the exchange rate.

We derive several important findings. First, the effect of the high interest rate policy on the won changes sign over time. A rise in the interest rate causes the exchange rate to depreciate over a very short period. But the increase in the interest rate induces the appreciation of the won after about four days, and the appreciation continues thereafter without substantial damping.

Second, the low interest rate policy induces a very short-run (less than five days) appreciation, but has no significant effects thereafter. A comparison between the high and low interest rate policies suggests a notable asymmetry in the exchange rate dynamics. Above all, the high interest rate policy induces a substantial appreciation over a long period, say more than thirty days, while the low interest rate policy has no impact on the exchange rate over the same period.

Third, the above results hold regardless of whether the interest rate is at the level of the pre-crisis period or the high interest rate period. This suggests that a further rise in the interest rate during the high interest rate period would have induced a further appreciation of the won, which may imply that the rise in interest rates recommended by the IMF during the Korean crisis was not excessive. It also suggests that a cut in the interest rate to the pre-crisis level could be achieved without causing depreciation.

These empirical findings suggest that the IMF's interest rate policy during the crisis contributed to the stabilization of the exchange rate. Our results also suggest that the rapid depreciation during the crisis was not temporary, which justifies the high interest rates in the initial period of crisis; and the asymmetric response suggests that a cut of the interest rate back to the pre-crisis level would not induce another serious exchange rate depreciation.

This paper is organized as follows. In the following sections, we discuss the empirical methodology, describe the data, and present the empirical results. We then evaluate the IMF's high interest rate policy and close with some concluding remarks.

2. Empirical Methodology

In contrast with earlier studies, we adopt the semi-nonparametric (SNP) method proposed by Gallant and Tauchen (1989). The key motivation for choosing a nonparametric model is that it allows us to conduct nonlinear impulse response analysis of the underlying dynamics, including potential asymmetries in the dynamic effects of interest rate policy on the exchange rate.

2.1. Semi-nonparametric Estimation of the Conditional Density[2]

Let y_t be the observed data at time t with dimension M, which have a Markovian structure. Markovian structure means that the conditional density of y_t given the entire history $(y_{t-1}, y_{t-2}, \ldots)$ depends on L lags from the past. Denote the one-step ahead conditional density of y_t as $f(y_t \mid x_{t-1})$, where $x_{t-1} = (y'_{t-L}, y'_{t+1-L}, \ldots, y'_{t-1})'$, which is a

[2] See Gallant and Tauchen (1989) for more detail.

vector of length M·L. Given the history of y_t, one can then determine the conditional density of y_t, $f(y_t \mid x_{t-1})$, by choosing q to minimize $s_n(q) \equiv -\frac{1}{n}\sum_{t=1}^{n} \log[f(y_t \mid x_{t-1}, q)]$ where n stands for the number of observations or by applying some conventional model selection criteria.

The SNP method is a semi-nonparametric density estimation based on an approximation of $f(y_t \mid x_{t-1})$ with Hermite series expansion. That is,[3]

$$f(y \mid x, q) \propto [P(z,x)]^2 \cdot n_M(y \mid m_x, \Sigma),$$

where $P(z,x)$ is a polynomial in the standardized error $z = R^{-1}(y - m_x)$ and the past data x, $\Sigma = RR'$ =(the variance and covariance matrix), $n_M(y \mid m_x, \Sigma)$ =(Gaussian density), and m_x is the linear conditional mean function of x_{t-1}, $m_x = b_0 + B \cdot x_{t-1}$. The constant of proportionality is $1/\int [P(z,x)]^2 f(z)dz$, which makes $f(\cdot)$ integrate to one. To achieve a unique representation, the constant term of the polynomial part is put to one.

When the density of z does not depend on x, it is a case of homogeneous innovations. When a multivariate polynomial of degree in z, K_z, is equal to zero, one gets $f(y \mid q) = n_M(y \mid m_x, \Sigma)$ exactly. When K_z is positive, one gets a Gaussian density whose shape is modified due to multiplication by a polynomial in the normalized error $z = R^{-1}(y - m_x)$. The shape modifications thus achieved are rich enough to accurately approximate densities from a large class that includes densities with fat, t-like tails, densities with tails that are thinner than Gaussian, and skewed densities (Gallant and Nychka, 1987). The tuning parameter K_z controls the extent to which the model deviates from normality.

To approximate conditionally heterogeneous processes, one can apply as above, except letting each coefficient of the polynomial be a polynomial of degree K_x in x. Therefore, the shape of the density depends on x when K_x is positive. All moments, thus, can depend on x, and the density can approximate any form of conditional heteroskedasticity. The tuning parameter K_x controls the extent to which the model's deviations from normality vary with the history of the process.

To capture ARCH/GARCH properties common in most financial variables, one can modify the variance-covariance matrix to depend on the absolute values of the elements of the vectors $(y_{t-L_r} - m_{x_{t-1-L_r}}, \ldots, y_{t-1} - m_{x_{t-2}})$. The variance-covariance matrix becomes:

[3] For notational convenience, we use variables with and without time subscript "t" interchangeably.

$$\Sigma_{x_{t-1}} = R_{x_{t-1}} R'_{x_{t-1}}$$

$$\text{vech}(R_{x_{t-1}}) = r_0 + \sum_{i=1}^{L_r} P_{(i)} \left| y_{t-1-L_{r+i}} - m_{x_{t-2-L_r+i}} \right| + \sum_{i=1}^{L_g} \text{diag}(G_{(i)}) R_{x_{t-2-L_g}+i}$$

where vech (R) denotes a vector of length M(M+1)/2 containing the elements of the upper triangle of R, r_0 is a vector of length M(M+1)/2, $P_{(1)}$ through $P_{(L_r)}$ are M(M+1)/2 by M coefficient matrices, $|y-m|$ denotes a vector containing the absolute values of $(y-m)$, and $G_{(1)}$ through $G_{(L_g)}$ are coefficient vectors with dimension of M(M+1)/2. The classical GARCH has $\Sigma_{x_{t-1}}$ expressed in terms of squared lagged residuals and lagged values of $\Sigma_{x_{t-1}}$. Therefore, the SNP version of GARCH is more akin to the suggestions made by Nelson (1991).

Large values of M can generate a large number of interactions such as cross product terms for even modest settings of degrees K_z and K_x. Accordingly, Gallant and Tauchen (1989) suggest two more additional tuning parameters, I_z and I_x, to filter out higher order interactions. I_z=0 means no interactions are suppressed. I_z=1 means the highest-order interactions are suppressed, namely those of degree exceeding $K_z - 1$. In general, a positive I_z means all interactions of order exceeding $K_z - I_z$ are suppressed. Similarly, a positive I_x implies the suppression of all interactions of order exceeding $K_x - I_x$. The relationship between parameter setting and properties of the processes are summarized in Table 1.

Table 1. Semi-Nonparametric Models

Parameter setting	Characterization of $\{y_t\}$
$L_m = 0, L_g = 0, L_r = 0, L_p \geq 0, K_z = 0, K_x = 0$	iid Gaussian
$L_m > 0, L_g > 0, L_r = 0, L_p \geq 0, K_z = 0, K_x = 0$	Gaussian VAR
$L_m = 0, L_g > 0, L_r = 0, L_p \geq 0, K_z > 0, K_x = 0$	Non-Gaussian VAR with homogeneous innovations
$L_m > 0, L_g > 0, L_r > 0, L_p \geq 0, K_z = 0, K_x = 0$	Gaussian GARCH
$L_m > 0, L_g > 0, L_r > 0, L_p \geq 0, K_z > 0, K_x = 0$	Non-Gaussian ARCH with homogeneous innovations
$L_m > 0, L_g > 0, L_r > 0, L_p \geq 0, K_z > 0, K_x > 0$	Full nonlinear non-Gaussian

Note: L_i's are the length for μ=(mean), g=(GARCH), r=(ARCH) and p=(polynomial part), and (K_z , K_z) are polynomial degrees in (z, x).

2.2. Impulse Response Analysis of Nonlinear Models[4]

In this subsection we describe strategies for eliciting the dynamics of the process $\{y_t\}$ as represented by $f(y \mid x)$. The analysis of impulse response functions developed by Sims (1980) has been widely used in the study of the dynamics of a linear process. The basic notion of an impulse response function under VAR analysis is to visualize the dynamic response of the system to a movement of an innovation that is a linear combination of iid innovations, u_t. In the general nonlinear case, however, there are various notions of an innovation, making it difficult to compute an impulse response function. However, if the impulse response function of the linear case is viewed as the perturbation of y_t instead of u_t, then the ideas from the linear VAR extend directly to the nonlinear case, as described in Gallant, Rossi, and Tauchen (1993).

On the assumption that the conditional density of the underlying process depends on at most L lags, the j-step ahead conditional mean profile given initial condition can be expressed by:

$$\hat{y}_j(x_0) = E(y_{t+j} \mid x_t = x_0) = \int y f^j(y \mid x_0)dy$$

where $f^j(y \mid x_0)$ denotes the j-step ahead conditional density

$$f^j(y \mid x_0) = \int \cdots \int \left[\prod_{i=0}^{j-1} f(y_{i+1} \mid y_{i-L+1}, \ldots, y_i) \right] dy_1 \cdots dy_{j-1}$$

with $x_0 = (y'_{-L+1}, \ldots, y'_0)'$. If x_0 is changed by $x^+ = x_0 + d$ or $x^- = x_0 - d$, for some vector value d in the conditional density, the j-step ahead conditional mean profile becomes

$$\hat{y}_j(x^+) = E(y_{t+j} \mid x_t = x^+) \equiv \hat{y}_j^+$$

for $x^+ = (y'_{-L+1}, \ldots, y'_0)' + (0, \cdots, d') \equiv x_o + d$, and

$$\hat{y}_j(x^-) = E(y_{t+j} \mid x_t = x^-) \equiv \hat{y}_j^-$$

for $x^- = (y'_{-L+1}, \ldots, y'_0)' - (0, \cdots, d') \equiv x_0 - d$, where j=1, ...,J. In a similar vein, $\hat{y}_j(x_0)$ stands for a baseline, which means the dynamics of conditional means without any perturbation in conditional arguments. Accordingly, positive and negative impulse responses of the J-step conditional mean are $\{\hat{y}_j^+ - \hat{y}_j^0\}_{j=1}^J$ and $\{\hat{y}_j^- - \hat{y}_j^0\}_{j=1}^J$, respectively. These two terms provide a nonlinear impulse response function for shocks on the conditional mean of the system.

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[4] See Gallant, Rossi, and Tauchen (1993) for more detail.

Analogously, we can measure the effects of perturbing conditional arguments on the J-step ahead conditional variance matrix. Define the M×M matrix as

$$\hat{v}_j(x_0) = E\left[\mathrm{Var}(y_{t+j} \mid x_{t+j-1}) \mid x_t = x_0)\right] = \int \Lambda \int \mathrm{Var}(y_j \mid y_{j-L-1}, \mathrm{K}, y_{j-1}) \left[\prod_{i=0}^{j-1} f(y_{i+1} \mid y_{i-L+1}, \mathrm{K}, y_i)\right] dy_1 \Lambda\, dy_{j-1}$$

for $j = 1,2,\mathrm{K}$, where $x_0 = (y'_{-L+1}, \mathrm{K}, y'_0)'$. The positive and negative impulse responses of perturbations $\boldsymbol{d}$ on the volatility are $\{\hat{v}_j^+ - \hat{v}_j^0\}_{j=1}^J$ and $\{\hat{v}_j^- - \hat{v}_j^0\}_{j=1}^J$, respectively.

3. Data

The data consist of the daily won/dollar spot exchange rate and Korean and U.S. three-month CD rates from January 4, 1995 to September 30, 1998, totaling 897 observations. Both data sets are obtained from Bloomberg. We use daily observations since these are what policymakers watched most closely to formulate interest rate policy during the crisis period, and weekly or monthly data might not yield statistically reliable results given that the high interest rate period was so short.

In our empirical analysis, we divide the overall period into three sub-periods: the pre-crisis period from January 4, 1995 to November 30, 1997; the crisis period (or high interest rate period) from December 1, 1997 to March 31, 1998;[5] and the post high interest rate period from April 1, 1998 to September 30, 1998. The numbers of observations are 709, 76, and 112 for each period. This period anatomy allows us to analyze how the dynamics of interest rates evolved around the crisis. The average levels of the interest rate in each period are used as a baseline initial condition for impulse response function analysis as described in the next section.

We restrict the pre-crisis period to 1995 onward because of structural changes in the won/dollar exchange rate suggested by previous studies. Joo and Kim (1999), for example, argue that exchange rate movements were well explained by macroeconomic fundamentals after 1995, but not from 1990 to 1995. The timing of the structural break coincides with the Korean government's efforts to liberalize the capital account, such as easing limits on stock investment in non-state owned companies by foreigners from 10 percent to 12 percent and opening the market for non-guaranteed convertible bonds issued by small and mid-size companies. Furthermore, Standard & Poor's upgraded Korea's sovereign credit rating from A2 to A1 in May 1995, which resulted in net capital inflows, an expansionary monetary policy, and won depreciation.

The high interest rate policy (HIRP) period was chosen in accordance with the movement of historical data and previous studies. The beginning of this period

[5] We use the terminology "crisis period" and "high interest rate period" interchangeably throughout the paper.

coincides with December 3, 1997, the date that the Korean government and the IMF agreed on the first Letter of Intent for the IMF program. As is well known, Korean interest rates rose rapidly around early December 1997. The Korean government also made an upward adjustment of the ceiling on the interest rate from 25 percent to 40 percent, as noted in the Letter of Intent of December 22, 1997. The HIRP period in our analysis is also consistent with Furman and Stiglitz (1998), who suggested that the period of high interest rates in Korea was 113 days long, from December 2, 1997 to late March of 1998.

As the final date of the post-crisis (or post-HIRP) period we choose September 1998, given that the Korean government announced the completion of the first-stage restructuring in October 1998.[6] In the post-HIRP period, the Korean economy was still feeling the aftereffects of the currency crisis and the interest rate was in a downward stabilization trend.

The won/dollar exchange rate and the differential between Korean and U.S. interest rates are illustrated in Table 2. The mean, standard deviation, and difference between the maximum value and the minimum value are largest during the HIRP period. In

Table 2. Basic Statistics

	Mean	Max	Min	Std. Dev.	Skewness	Kurtosis
KRW/USD						
Whole Period	1038.4	1962.5	753.0	238.6	0.611	2.79
Pre-HIRP	814.5	915.0	753.0	49.2	0.608	1.91
HIRP	1360.5	1962.5	912.6	228.5	-0.311	2.82
Post-HIRP	1173.3	1389.0	1102.5	57.1	1.066	4.18
Interest Differential						
Whole Period	6.16	19.81	0.59	4.25	0.737	3.50
Pre-HIRP	7.79	11.16	4.73	1.27	0.207	2.71
HIRP	12.06	19.81	5.30	4.33	0.155	1.78
Post-HIRP	1.78	6.11	0.59	0.87	1.146	5.07

Notes: 1) The pre-HIRP period is between January 4, 1995 and November 30, 1997, the HIRP period between December 1, 1997 and March 31, 1998, and the post-HIRP period between April 1, 1998 and September 30, 1998.

2) The interest rate differential is between Korean and U.S. interest rates.

[6] Of course, it is possible to include the data from October 1998 up until this day for our empirical analysis.

addition, the exchange rate distribution is skewed to the left during the HIRP period, while the interest rate differential in the same period is skewed to the right. This suggests that the interest rate had an upward trend whereas the exchange rate had an appreciation trend during the HIRP period. Further, during the post-HIRP period, both variables show different characteristics from a normal distribution.

For our empirical analysis, we focus on relation between the percentile change in the won/dollar spot exchange, denoted by *exch* ($=100\times\ln[s_t / s_{t-1}]$), and the differential between Korean and U.S. interest rates, denoted by *int*, bearing the interest parity in mind.

4. Main Empirical Results

The SNP estimation provides information regarding an appropriate statistical model describing the dynamics of the two variables, *exch* and *int*, reasonably well. Based on the estimated SNP specification, the impulse response analysis allows us to see the direction and duration of the effects that changes in the interest rate have on the exchange rate, more precisely on the percent change in the exchange rate.

We conduct the SNP estimation from January 4, 1995 to September 30, 1998 to capture the underlying dynamic structure over the full period since the high interest rate policy during the Korean crisis may have been adopted based on the past behavioral relation between interest rates and exchange rates. At the same time, if policymakers believed that high interest rates could lead to structural changes, they might have a forward looking perspective.[7]

Through the SNP estimation we can identify the parameters driving the dynamics of the model. Given that the SNP approach is based on a truncated Hermite series expansion, we need to determine the key parameters: the degrees of the polynomial (K_z, K_x) and the lag lengths of the mean, the GARCH and the polynomial part (L_m, L_g, L_r, L_p). For this purpose, we use the Bayesian Information Criterion (BIC) as a selection strategy. Table 3 shows the objective surface for SNP estimation and the selected values for the parameters. From the table, we can see that $L_m = 4$, $L_g = L_r = L_p = 1$, $K_z = 4$, $I_z = 2$, $K_x = I_x = 0$ are the most appropriate selection based on BIC. This suggests that the model has four lags in the linear autoregressive component, GARCH(1,1), and non-Gaussian error structure reflected by the fact that a polynomial of degree 4 in z is

[7] Fischer (1998) suggests that the high interest rate policy would help restructure an economy as well as restore confidence.

selected. In summary, the density is a GARCH model with a non-parametric error structure.

Table 3. Bivariate SNP Estimation

L_u	L_g	L_r	L_p	K_z	I_z	K_x	I_x	P_θ	S_n	BIC
1	0	0	1	0	0	0	0	9	0.670	0.705
2	0	0	1	0	0	0	0	13	0.598	0.648
3	0	0	1	0	0	0	0	17	0.573	0.638
4	0	0	1	0	0	0	0	21	0.552	0.633
5	0	0	1	0	0	0	0	25	0.546	0.643
4	1	1	1	0	0	0	0	30	-0.911	-0.795
4	1	1	1	4	3	0	0	38	-1.094	-0.948
4	***1***	***1***	***1***	***4***	***2***	***0***	***0***	***39***	***-1.106***	***-0.956***
4	1	1	1	4	1	0	0	41	-1.111	-0.953
4	1	1	1	5	4	0	0	40	-1.097	-0.943
4	1	1	1	5	3	0	0	41	-1.098	-0.940
4	1	1	1	6	5	0	0	42	-1.098	-0.936
4	1	1	1	4	3	1	0	56	-1.130	-0.914
4	1	1	1	4	2	1	0	59	-1.135	-0.908
4	1	1	1	5	4	1	0	62	-1.129	-0.890
4	1	1	1	6	5	1	0	68	-1.136	-0.8742

Notes: 1) L_i' s represent the lag length for μ=(mean), g=(GARCH), r=(ARCH), and p=(polynomial part).

2) (K_z , K_z) are polynomial degrees in (z, x).

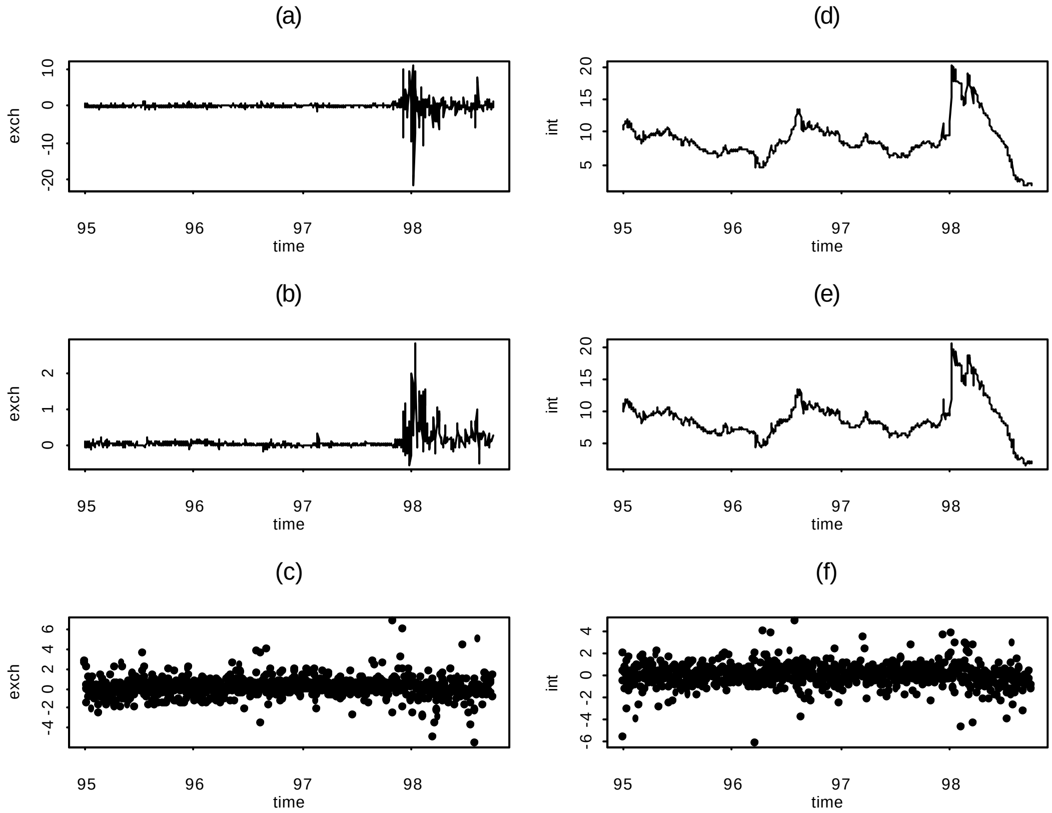
3) P_θ is the number of free parameters in the model.

4) S_n is the log likelihood value, and BIC stands for Bayesian Information Criterion.

4) Bold and italic characters denote the chosen empirical model based on the minimized BIC value.

Figure 1 presents information on the adequacy of the fit of the estimated model, as in Tauchen (1997) and Chung and Tauchen (2001). A comparison of panels (a) and (d), which show the dynamic behavior of the raw data, and panels (b) and (e), which show the estimated one-step ahead conditional means, indicates that the estimated model does a good job of tracking the mean over the sample period. Panels (c) and (f) are scatter plots of the standardized residuals — the difference between the raw data and the estimated conditional mean — of each variable. The scatters are reasonably uniform in the vertical direction, suggesting a good fit.

Figure 1. Dynamics of Raw Data and SNP Estimation



Note: Panel (a) is a plot of daily observations on the rate of change in the won/dollar exchange rates (*exch*) from January 4, 1995 to September 30, 1998, while panel (d) is a plot of the interest rate differential between Korea and the U.S. (*int*) during the same period. Panels (b) and (e) are plots of the SNP one-step ahead conditional mean for *exch* and *int*, respectively. Panels (c) and (f) are normalized residuals for *exch* and *int*, respectively.

Within the estimated SNP dynamic structure, we now carry out the analysis of nonlinear impulse response function to investigate the effect of interest rate policy in the pre-HIRP economic environment, when interest rates are lower than they are in the HIRP period. To flesh this out, we empirically investigate how the exchange rate responds to both an upward and a downward adjustment of the interest rate from the average interest rate of the pre-HIRP period. The experiment is expected to provide information on which of the two policies, high and low interest rate policies, would have contributed more effectively to the stability of the exchange rate in the pre-crisis (or the pre-HIRP) economic environment.

A more precise description of this experiment is as follows. Let $x_0 = (y'_{-L+1}, \ldots, y'_0)'$

be a vector of the averages of *exch* and *int* during the pre-HIRP period. We can then see the effects of an increase in the interest rate differential on the dynamic path of *exch*, which is the rate of change of exchange rates, by changing the conditional arguments x_0 into $x_0^+ = x_0 + (0, \ldots, \boldsymbol{d}')' \equiv x + \boldsymbol{d}$ where $\boldsymbol{d} = (0, y_{\text{int}})'$, $y_{\text{int}} = \boldsymbol{z} \times$[average level of pre-HIRP interest rate differential], for $\boldsymbol{z}$ =0.1, 0.4, and 0.8. That is, we empirically analyze how increases of 10 percent, 40 percent, and 80 percent in the interest rate differential from the pre-HIRP average interest rate differential would affect the change in the exchange rate.[8] We can also easily see the effect on the exchange rate of a decrease in the interest rate differential by putting $\boldsymbol{z}$ =-0.1, -0.4, and -0.8.

Figure 2 shows the response of the rate of change in the exchange rate (*exch*), to each of the above-mentioned interest rate shocks on the pre-HIRP interest rate differential. From the experiment, we derive the following key findings, which hold regardless of the absolute size of the shock.

First, the effect of the high interest rate policy on the exchange rate changes sign over time. For a very short period, the conditional mean of *exch* stays above zero, suggesting that a rise in the interest rate causes the exchange rate to depreciate. After four days or so, however, the effect is reversed and the conditional mean becomes negative, which suggests that the increase in the interest rate induces an appreciation of the won. The appreciation effect of the HIRP shock is persistent without substantial damping.[9][10] The dynamic patterns of the exchange rate responses show a remarkable uniformity, especially about the timings of the reversal, regardless of the size of the shock.

Second, the low interest rate policy appreciates the exchange rate only for an extremely short period, but it has no significant effect afterwards. As seen in Figure 2, the low interest rate policy appreciates the won for less than five days. But the effect is almost nil thereafter, at least in terms of deviations from the baseline. This pattern also holds regardless of the size of the shock, with the timing of when the exchange rate effects vanish almost the same for different sizes of the shock.

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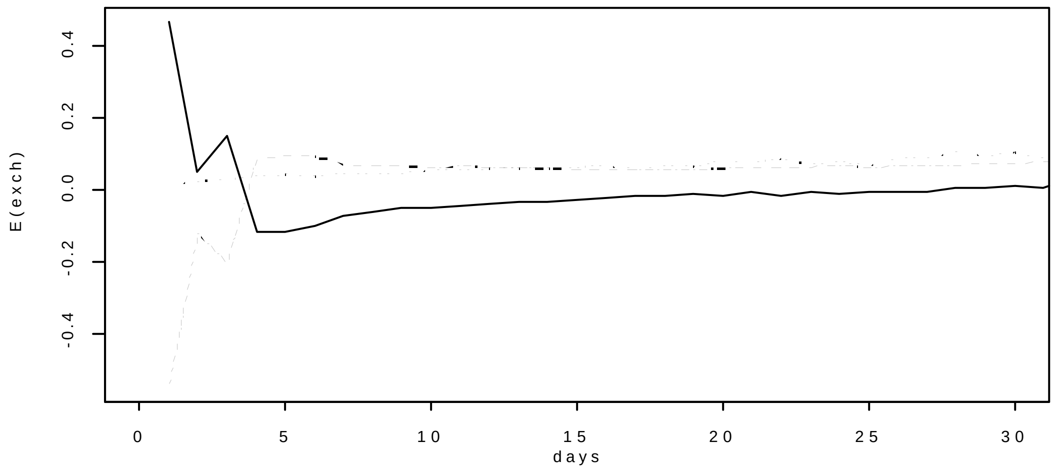
[8] 80 percent in this case is the level necessary for the pre-crisis average interest rate to reach the maximum interest rate level during the HIRP period.

[9] In Figures 2 and 3, the chart for the impulse response function is drawn for 30 days, because the shape of the impulse response after 30 days is not much different from the one just before 30 days.

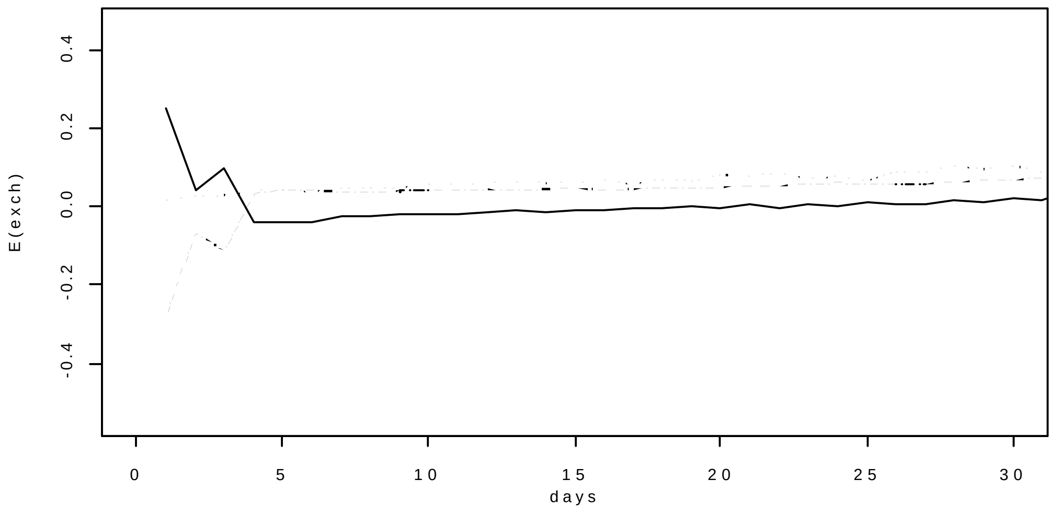
[10] Whether the effect of a shock is persistent or not would depend on the definition of persistency. The responses in the experiment, however, remain at substantial magnitudes, more than 10 percent of the total deviations from the baseline.

Figure 2. Impulse Response Function of Changing Interest Rates in the Pre-HIRP Economic Environment

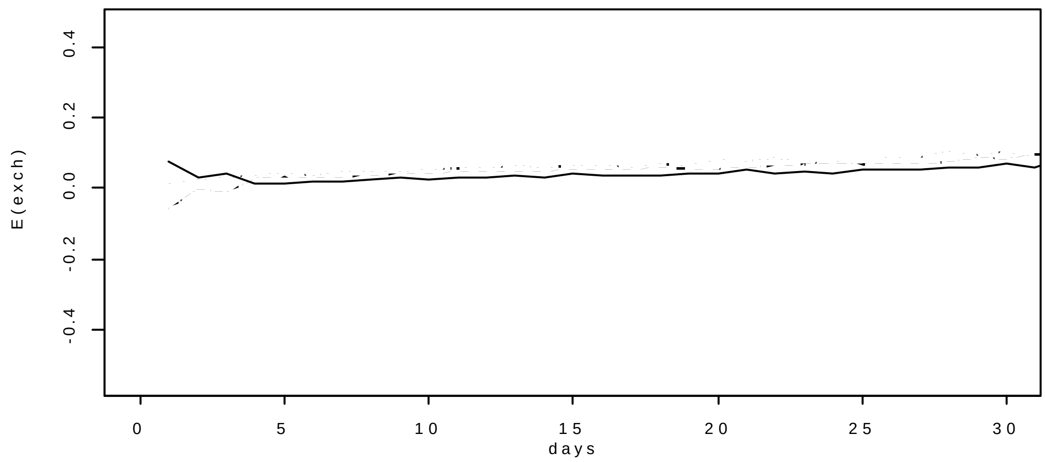
(i) 80 percent interest rate shock



(ii) 40 percent interest rate shock



(iii) 10 percent interest rate shock



Note: The y-axis is the conditional mean of *exch*, the percent change in the won/dollar exchange rate. The dotted line (·····) indicates the baseline. The solid line (—) and the dashed line (-·-·-·) are the responses to a positive and negative shock to the interest rate, respectively.

A comparison between the two policy options, high interest rate policy and low interest rate policy, suggests a notable asymmetry in the exchange rate dynamics. The high interest rate policy induces a substantial appreciation over a long period, say more than thirty days, while the low interest rate policy may affect the exchange rate only over an extremely short period.

Now we look at the effect of interest rate policy on exchange rate dynamics during the HIRP period. More specifically, we examine how the exchange rate responds to an increase or a decrease in the interest rate from the average interest rate of the HIRP period. This experiment is expected to reveal some useful information on the appropriate policy prescription during the crisis period, particularly whether it would have been effective to further raise or cut the interest rate during that period.

In this experiment, we choose ±0.1, ±0.3 and ±0.5 for the value of z, the percent increase or decrease in the interest rate differential from the average level during the crisis period. The maximum value for z, 0.5, is the ratio of the highest interest rate to the average interest rate during the HIRP period.

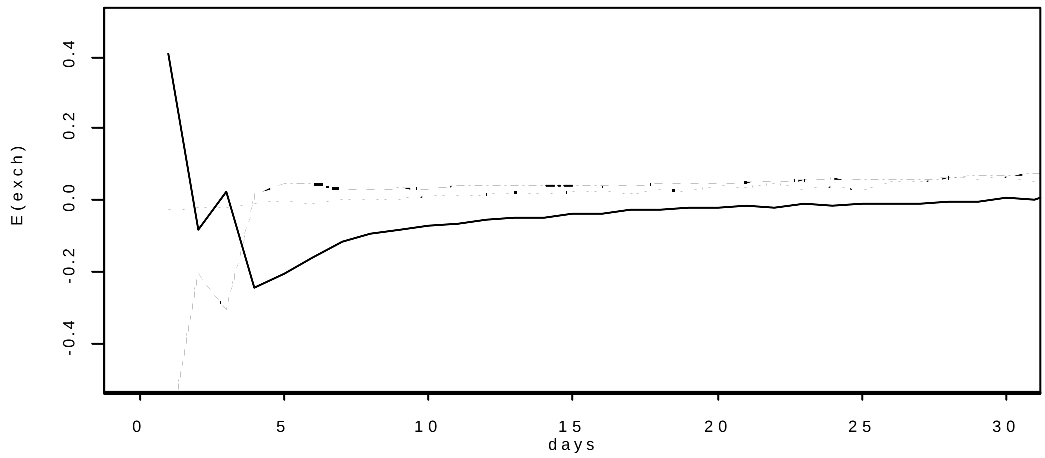
Figure 3 illustrates the effects on the exchange rate of shocks on the HIRP interest rate. The key results for the pre-HIRP period hold for the HIRP period. This suggests that a further rise in interest rates during the HIRP would have induced a further appreciation of the won. Thus, it would have been appropriate to continue to raise the interest rate during the HIRP period if policymakers had believed that the exchange rate would have continued to depreciate further. This suggests that the rise in the interest rate recommended by the IMF during the Korean crisis was not excessive.

The results also suggest that a cut in interest rates below the level prevailing during the HIRP period would not have induced a significant depreciation over the three-month period.[11] This appears consistent with the fact that the exchange rate in Korea remained stable even after interest rates were cut back to the pre-crisis level.

The above findings shed new light on the literature on the efficacy of high interest rate policy. In particular, our empirical results may reconcile seemingly inconclusive and mutually inconsistent evidence suggested by the previous studies. Our results suggest that the reason why some empirical studies (for example, Goldfajn and Baig, 1998) using daily data find that the high interest rate policy has little or negative effect on the exchange rate may be because they do not allow for nonlinearities. In addition, our finding that the depreciation effect of the high interest rate policy is reversed after around four days suggests that if weekly or monthly data are used (as in Dekle et al, 1998; and Cho and West, 2001), the likelihood of having a positive effect would be higher.

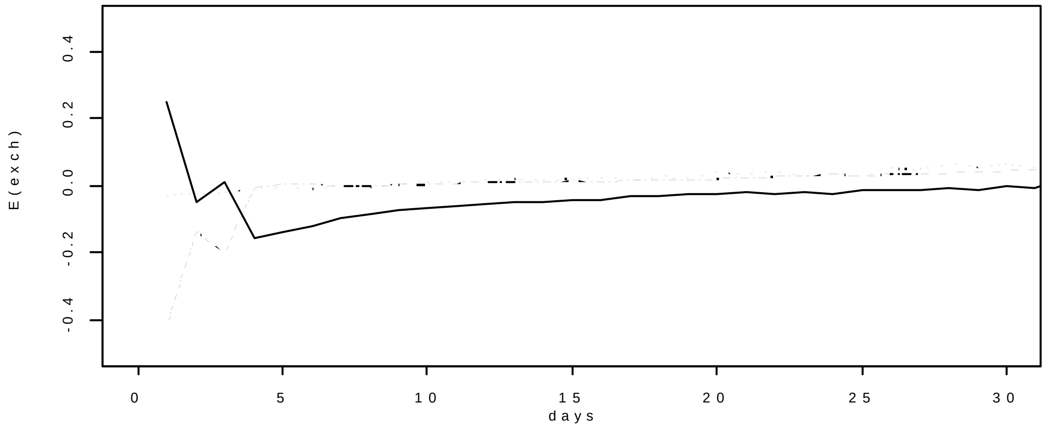
Figure 3. Impulse Response Function of Changing Interest Rates with HIRP Economic Environment

(i) 50 percent interest rate shock

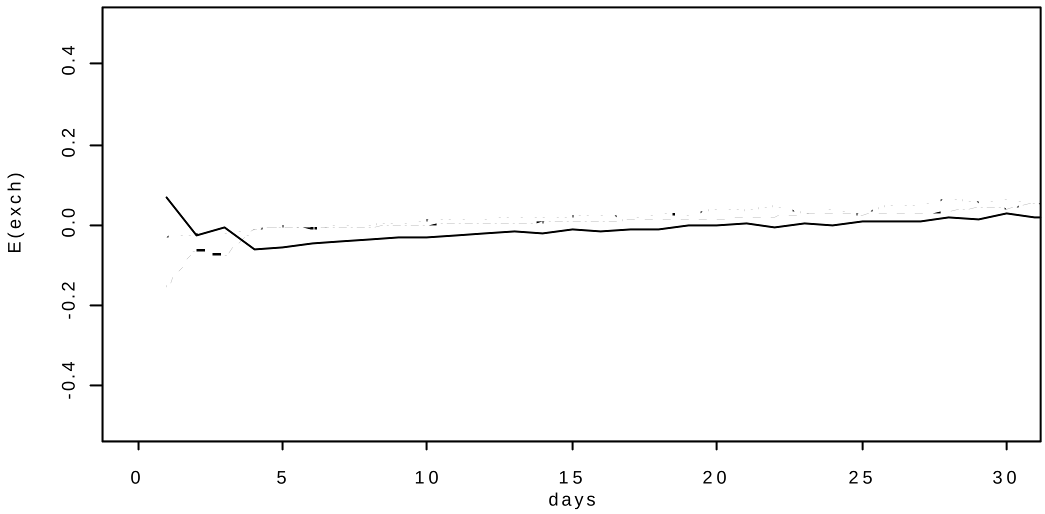


[11] The effect of a decrease in the interest rate seems to revert back to the baseline more slowly during the HIRP period than during the pre-HIRP period.

(ii) 30 percent interest rate shock



(iii) 10 percent interest rate shock



See note to Figure 2.

5. Evaluation of the IMF's High Interest Rate Policy

Our empirical results provide some building blocks to assess whether the IMF's high interest rate policy prescription for Korea during the crisis was appropriate. The assessment would depend partly on how long the underlying trend of depreciation of the won against dollar would have continued. If the depreciation of the won had been very short-lived, less than five days or so, and small, then a low interest rate policy would have been a better policy option. If, however, the depreciation was expected to persist much longer, say one month, then a high interest rate policy would be more effective.

There is evidence that the sharp rise in the won/dollar rate would last for longer than a week, implying that the high interest rate policy was appropriate. In particular, the baseline movements in our impulse response analysis show a depreciation trend for at least a month (see Figures 2 and 3). This implies that our SNP estimation detected the realized depreciation trend of the won/dollar exchange rate during the pre-HIRP and HIRP periods, which coincide with observed data as shown in Figure 1.

Depreciation pressures lasting for an extended period may reflect the following circumstances at the onset of the crisis. First, there was no easy way to resolve the short-term external liabilities, which acted as a major cause of the currency crisis in Korea,[12] within a short period. This is obvious from the fact that it was three months after the eruption of the crisis before Korea could begin the debt rescheduling process of converting the US$20 billion short-term liabilities to long-term liabilities. Short-term debts continued to be called in despite financial assistance from the IMF beginning on December 3, 1997.

Second, it took a while for the once-depleted foreign reserves to be rebuilt. As domestic banks, faced with refusal of maturity extension by international creditor banks, were unable to raise funds in foreign currency on their own, the Bank of Korea provided them with contingency funds out of the foreign exchange reserves, which together with excessive foreign exchange market intervention led to the depletion of foreign exchange reserves. The massive re-accumulation of foreign exchange reserves that was obviously necessary to restore investor confidence would have taken more than just a couple of months.

Third, it is not easy for an economy to restore its credit ratings after they have been downgraded. During the crisis, international credit rating agencies quickly downgraded Korea's sovereign credit rating. For instance, Standard & Poor's downgraded Korea's credit rating by ten notches from October to December 1997, and Moody's downgraded six notches on three occasions. The rating of these agencies had an enormous impact on bond and stock investment in Korea, which in turn contributed to the devaluation of the Korean won. Given the difficulty of restoring the credit rating back to its normal level, the depreciating trend of the won was likely to continue for some time.

In sum, our empirical results suggest that the IMF's recommendation of high interest rates was an effective policy for stabilizing the exchange rate. In particular, the

[12] This factor is noted as the variable that best predicts the likelihood of a crisis in some empirical analysis. See Park and Choi (1998) and references therein.

asymmetric effects of policy alternatives suggest that raising the interest rate was appropriate at the onset of the crisis while devaluation pressures persisted; and that the subsequent cut in the interest rate was also effective, as the initial uncertainty dissipated.

6. Conclusion

This study has evaluated the effectiveness of the high interest rate policy in stabilizing the exchange rate in Korea during the crisis. A nonlinear impulse response approach was adopted for a number of reasons. First, the nonlinear model is more general and provides richer dynamics of exchange rate responses to an interest rate shock. In addition, the nonlinear model provides a useful analytical tool to detect potential nonlinearities, particularly the asymmetric response of the exchange rate to an increase compared with a decrease in interest rates.

We found that the effect of the high interest rate policy on the exchange rate changes sign over time. A rise in the interest rate causes the exchange rate to depreciate only for four days or so. However, the increase in the interest rate induces the appreciation of the won afterwards, and the appreciation continues thereafter without substantial damping. We also found that the low interest rate policy appreciates the exchange rate only for an extremely short period, but has no significant effect afterwards. So there is a distinctive asymmetry in the exchange rate response to an interest rate shock. We also suggest that the mixed assessments of previous studies on the efficacy of high interest rate policy in Korea might have their root in the span of the data and the assumption of a linear relationship between interest rates and exchange rates.

Our empirical results also suggest that the IMF' s high interest rate policy during the crisis, which was characterized by a sharp increase in interest rates at the onset of the crisis followed by a cutback after several months, was an effective policy prescription for exchange rate stabilization. If the sudden rise in the won/dollar rate was deemed extremely temporary (less than five days), then a low interest rate policy would have been more appropriate. Nevertheless, the economic situation at the time of crisis suggests that the rapid rise in the exchange rate was not temporary. Therefore, the high interest rate policy was appropriate in the situation. Our result also suggests that a cut of the interest rate back to the pre-crisis level would be achieved without another serious exchange rate depreciation, supporting for the policy of cutback of interest rates after several months.

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