Long Memory Property and Central Bank Intervention in Foreign Exchange Market: The Case of Daily Korea Won-US Dollar Exchange Rate During the Currency Crisis*

by

Young Wook Han+

Department of Economics and Finance,

City University of Hong Kong,

Kowloon, Hong Kong.

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+Corresponding: E-mail:efhanmsu@cityu.edu.hk., Phone:+852-2788-7312, Fax:+852-2788-8806

Abstract

This paper considers the use of the long memory volatility process, FIGARCH, in representing Korean Won – US Dollar daily spot exchange rates. The spot returns are found to exhibit the widespread long memory property in both their conditional variances and also their absolute returns; hence the FIGARCH model is found to be the preferred specification for the daily returns data. Interestingly, the long memory parameter during the currency crisis is found to be greater relatively to that of the post-crisis period in which the period of the crisis is excluded, implying that the volatility process seems to be more persistent during the crisis.

And, this paper quantifies the effectiveness of the interventions by Bank of Korea (BOK) to curtail the massive depreciation of Korean won during the crisis. General conclusions provide some econometric evidences that the interventions were not effective at all in preventing further depreciation of Korean won rather caused it to be worse, but they had slight effects on the volatility of its foreign exchange market so that they seemed to be successful in making the disorderly market calm by reducing the volatility of the market a little bit. And, any significant evidence that the interventions influenced on a time dependent risk premium is not found.

Keywords: Daily Korean Won-US Dollar Exchange Rates, Long Memory property, FIGARCH, Intervention, Risk Premium.

JEL classifications: C22, F31

1. Introduction

Recently the long memory, persistent property in volatility process has become a well documented feature of the foreign exchange markets; e.g. see Andersen and Bollerslev (1998) and Baillie, Cecen and Han (2000). But, little is known about the Korean exchange rates. This paper uses a set of daily data for Korean won vis a vis the US dollar. The exchange rate returns are found to exhibit the widespread long memory, persistent property in both their conditional variances and also their absolute returns. The long memory volatility parameter is estimated by the FIGARCH model of Baillie, Bollerslev and Milkkelsen (1996) which has been found to provide good descriptions of daily return volatility. Also, the estimated long memory parameter is compared with that of the post-crisis period, from October 1, 1998 to December 31, 2001, as defined by Park, Chung and Wang (2001).

The intervention activity has been used by many central banks like Federal Reserve Bank, Bundesbank and Bank of Japan especially at the end of 1980s through the early 1990s and recently by central banks of Asian countries like Korea, Thailand and Malaysia in 1997 during the currency crisis. Despite the popular usage as a policy instrument, there has been a controversy over the effectiveness of intervention as a policy tool because there are still many debates over whether it can achieve the policy objectives of either influencing the level of nominal exchange rates or reducing their volatility. In this context, some papers like Sachs and Woo (2000) and Kim (2000) reported that the inappropriate interventions and the problematic exchange rate policies of the Asian countries may be one of the main causes of the currency crisis in 1997. For this reason, the events of the Korean currency market especially during the crisis throw some light on the controversies that have existed in recent years, on the effectiveness of central bank intervention. Thus, this paper investigates the direct quantitative effect of the interventions in the foreign exchange market, which were undertaken by Bank of Korea (BOK) during the period of the currency crisis in Korea, and explores whether the interventions were effective as a policy tool. And, another interesting viewpoint proposed by Baillie and Osterberg (1997b) is that intervention affected risk premium over uncovered interest rate parity (UIP) even though the risk premium is not the target of the intervention. This paper also discusses briefly whether the interventions can help explain the risk premium especially during the currency crisis.

The plan of the rest of this paper is as follows: section 2 estimates of some long memory ARCH, or FIGARCH models on the spot return series, which are found to provide a good description of the volatility process of the returns series. And, the long memory parameter of the post-crisis period is estimated for the comparison. Confirmatory evidence from a semi parametric Local Whittle estimator is also given. Section 3 presents the econometric evidence on the effects of the intervention of BOK during the crisis. The interventions appeared not to be successful in terms of inducing a Korean won appreciation but they could affect the volatility of the market slightly. Section 3 also reports estimates of the impact of the level of intervention on the deviation of the nominal exchange rate from uncovered interest rate parity (UIP). This model is in accord with the portfolio balance approach and also the model of the time varying risk premium developed by Baillie and Osterberg (1997b). This paper found that there is not any significant econometric evidence that the interventions of BOK are associated with the risk premium over uncovered interest rate parity (UIP). Section 4 then provides a brief conclusion of the results in the paper.

2. Analysis of Daily Korean won-US dollar Returns

This section is concerned with the analysis of daily Korean Won-US Dollar exchange rate returns by using a FIGARCH model to describe daily volatility. The set of the daily W-$ spot exchange rates is obtained from Datastream with the sample period of July 2, 1997 through December 31, 2001, which correspond to the start of the Asian Crisis[1)]. Excluding weekends and holidays, the spot returns realize a sample of 1174 daily observations. The time series realizations of the spot exchange rates for the daily Korean won-US dollar are plotted in figure 1. The extreme turbulence in the market is also seen to induce the heavy tailed, undefined variance of unconditional returns phenomenon, as studied by Koedijk, Schafgens and de Vries (1990). The autocorrelation function of the daily returns, squared returns and absolute returns are plotted in figure 2. In particular, the autocorrelations of the squared returns and absolute returns exhibit very slow, persistent decay that is typical of asset prices determined in speculative auction markets, see Ding, Granger and Engle (1993). The model that is postulated to describe the returns process is then,

(1) $$R_t = 100 * \text{Ä}\ln(S_t) = \text{å}_t + \theta\, \text{å}_{t-1},$$

(2) $$\text{å}_t = z_t \text{ó}_t,$$

(3) $$\text{ó}^2_t = \text{ù} + \text{â}\text{ó}^2_{t-1} + [1 - \text{â}L - (1 - \text{ö}L)(1 - L)^{\text{ä}}]\text{å}^2_t,$$

where S_t is the daily W-\$ spot exchange rate, z_t is i.i.d.(0,1) and returns are specified to follow a MA(1) process, while the conditional variance process ó^2_t, in equation (3), is represented by a FIGARCH (Fractionally Integrated Generalized AutoRegressive Conditional Heteroskedastic) process, as developed by Baillie Bollerslev and Mikkelsen (1996). The above FIGARCH(1,ä,1) process is sufficiently general that it can generate very slow hyperbolic rate of decay in the autocorrelations of squared returns. When ä = 0, p = q = 1, then equation (3) reduces to the standard GARCH(1,1) model; and when ä = p = q = 1, then equation (3) becomes the Integrated GARCH, or IGARCH(1,1) model, and implies complete persistence of the conditional variance to a shock in squared returns. The FIGARCH process has impulse response weights, $ó^2_t = ù/(1 - â) + ë(L)å^2_t$, where $ë_k$. k^{d-1}, which is essentially the long memory property, or "Hurst effect" of hyperbolic decay. The attraction of the FIGARCH process is that for 0 < ä < 1, it is sufficiently flexible to allow for intermediate ranges of persistence. Analogous behavior in the conditional mean of exchange rates has been considered by Cheung (1993). The simpler FIGARCH(1,ä,0) process is of the form,

$$ó^2_t = ù + âó^2_{t-1} + [1 - âL - (1 - L)^{ä}]å^2_t.$$

The equations (1) through (3) are estimated by using non-linear optimization procedures to maximize the Gaussian log likelihood function,

$$(4) \qquad \log(\ \ ) = -(T/2)\ln(2ð) - (1/2)Ó_{t=1,T}[\ln(ó^2_t + å^2_t ó^{-2}_t)],$$

with respect to the vector of parameters denoted by è. Since most return series are not well described by the conditional normal density in (4), subsequent inference is consequently based on the Quasi Maximum Likelihood Estimation (QMLE) technique of Bollerslev and Wooldridge (1992), where

$$(5) \qquad T^{1/2}(\hat{è}_T - è_0)\ Ψ\ N\{0, A(è_0)^{-1}B(è_0)A(è_0)^{-1}\},$$

and A(.) and B(.) represent the Hessian and outer product gradient respectively; and $è_0$ denotes the true parameter values.

Figure 3 presents the correlograms of the standardized residuals from the MA(1)-FIGARCH (1,ä,1) model. In particular, the long memory property disappeared significantly in the squared and absolute terms, implying that FIGARCH model appears to be quite successful in representing the long memory volatility process of the daily W-$ spot returns. And, the results of the estimated model for the daily spot exchange rate returns are presented in table 1(a). The estimate of the long memory parameter, ä, for daily data is about 0.83. This estimate is close to the estimate of the persistence parameter presented in Lee (2000) who used the Stochastic Volatility (SV) model. Table 1(a) also shows that the estimates of ä are statistically significant at the .01 percentile. The model reported in table 1(a) for the currency appears satisfactory and do not suffer from any obvious misspecifications. Various tests for specification of the daily model were performed[2)]. In particular, a robust Wald test of a stationary GARCH(1,1) model under the null hypothesis versus a FIGARCH(1,ä,1) model under the alternative hypothesis has a numerical value of 106.6, which shows a clear rejection of the null when compared with the critical values of a chi squared distribution with one degree of freedom. Hence there is strong support for the hyperbolic decay and persistence as opposed to the conventional exponential decay associated with the stable GARCH (1,1) model[3)]. This result is quite in consistent with Beine, Benassy-Quere and Lecourt (2002) who found that FIGARCH model appears to outperform the traditional GARCH model. A sequence of diagnostic portmanteau tests on the standardized residuals and squared standardized residuals failed to detect any need to further complicate the model. Also, given the extreme turbulence that occurred in the market, the estimated model in table 1(a) has relatively little excess kurtosis in the standardized residuals especially when compared with recent period high frequency data presented in Andersen and Bollerslev (1998) and Baillie, Cecen and Han (2000). And, the estimated long memory parameter (δ) from the whole period is compared with that of the post-crisis period, from October 1, 1998 to December 31, 2001, which is defined by Park, Chung and Wang (2001)[4]. The result of the post-crisis period is also presented in table 1(a). The estimated long memory parameter (δ) of the post-crisis period, 0.51, is smaller than that of the whole period including the crisis. This result is in accord with Lee (2000) who showed that the persistence of volatility process of the similar daily Korea won-US dollar returns increased after the currency crisis started by using the Stochastic Volatility (SV) model.

Also, the long memory parameters in the absolute spot returns series are estimated by a Local Whittle estimator proposed by Taqqu and Teverovsky (1997). If $f(v_j)$ is the spectral density of the absolute returns series, then the local Whittle estimator only requires specifying the form of the spectral density close to the zero frequency. For a long memory process, $f(v_j) \approx g(\delta)|v_j|^{-2\delta}$, as $v_j \to 0$, and for $g(\delta)$ which is some function of δ. The local Whittle estimator then minimizes the quantity,

(6) $$R(d) = \ln[(1/m) \Sigma_{j=1,m} [I(v_j) v_j^{-2\delta}] - (2\delta/m) \Sigma_{j=1,m} [\ln(v_j)],$$

where $I(v_j) = (2\pi T)^{-1} |\Sigma_{t=1,T} |y_t| \exp(itv_j)|^2$, and is the periodogram of the absolute returns series, $|y_t|$. The local Whittle estimator appears particularly desirable in situations where the long memory dependence of a time series is compounded by very non Gaussian, fat tailed densities. Taqqu and Teverovsky (1997) report detailed simulation studies of various semi parametric estimators for long range dependence and find the local Whittle estimator to perform well in extreme non Gaussian cases. The estimator depends on the number of low frequency ordinates being used. The estimates of the long memory parameters (δ) for the absolute returns series of the tow periods are reported in table 1(b), and they are very close to the values of the estimated long memory parameter in the FIGARCH models in table 1(a).

3. Effects of Intervention of the Bank of Korea on Foreign Exchange Market

Baillie, Humpage and Osterberg (2000) has pointed out that the official intervention in the foreign exchange market is generally defined as the official purchases and sales of foreign currencies by the central bank to influence the future currency movement, and the intervention is assumed to be sterilized so that the purchase (sale) of foreign currency is exactly offset by a corresponding sale (purchase) of domestic government debt to eliminate the effects on domestic money supply. Thus, following Baillie, Humpage and Osterberg (2000) paper, this section focuses on the effects of the official interventions (which are assumed to be sterilized) conducted by Bank of Korea particularly during the crisis period by excluding other types of intervention such as domestic monetary policies and the so called "jawboning" intervention, where the monetary authorities issue statements designed to affect the foreign exchange market.

Even though the historical origins of the sterilized intervention as a policy tool is not entirely clear, one of the earliest interventions is the one occurred in the French currency market in 1924, which is sometimes referred as the "*Poincare bear squeeze*". Recently Baillie and Han (2002) found the intervention of French government in 1924 appeared to be highly successful in appreciating French Franc without affecting the volatility of the currency market. And, in the recent post Bretton Woods era, the intervention has typically intended to move the level of a nominal exchange rate to a target level, or to "calm disorderly markets", i.e. reduce volatility. Both intentions have been articulated at the Plaza

Agreement in September, 1985 and at the Louvre Accord of February, 1987. As reported by Humpage (1988, 1997), Baillie and Osterberg (1997a) and other authors, studies in the modern period have generally found a "leaning against the wind" phenomenon, with a central bank buying (selling) a currency, being associated with that currency depreciating (appreciating). Also, they found that intervention increased the exchange rate volatility rather than reduced it. Thus, there has been a controversy over the effectiveness of intervention as a policy tool, whether it can achieve the policy objectives of either influencing the level of nominal exchange rates or reducing their volatility.

Similarly, the intervention activity has been used frequently by central banks of many Asian countries like Korea, Indonesia, Thailand and Malaysia especially during the currency crisis. In particular, Korean currency market experienced the substantial changes in the exchange rate system from the managed floating system from the freely floating system in 1997, and the nominal exchange rate of W-$ depreciated significantly about 80% during the crisis. As the expectations of future depreciation increases, Bank of Korean started to intervene in the foreign exchange market in order to increase the value of Korean won and prevent further massive depreciation. However, as Kim (2000) pointed out that the inadequate intervention in the foreign exchange market was one of the critical factors which led to the currency crisis in Korea, there have existed debates over the effectiveness of intervention as a policy tool during the crisis. Hence, this section investigates the effects of interventions conducted by BOK during the crisis by using a generalized FIGARCH model with a dynamic dummy variable.

Since the daily official intervention data of BOK is not available to the public, the data set has been indirectly constructed by collecting articles from the electronical archives of the Dow Jones International News from July 2, 1997 to September 30, 1997. The data showed that during the crisis period BOK has conducted totally 40 interventions by selling US$ in order to support the value of Korean Won and smooth the volatility in the currency market[5)].

In order to investigate the effects of the interventions, it is convenient to estimate the model,

(7) $$y_t = 100.\text{Äln}(S_t) = \text{ì} + [\text{á}_0 /(1 - \text{ë}_0 L)]D_t + \text{å}_t + \text{èå}_{t-1} ,$$

(8) $$\text{å}_t = z_t \, \text{ó}_t,$$

(9) $$\text{ó}^2_t = \text{ù} + \text{âó}^2_{t-1} + [\text{á}_1/(1 - \text{ë}_1 L)]D_t + [1 - \text{â}L - (1 - L)^{\text{ä}}]\text{å}^2_t ,$$

where z_t is i.i.d.(0,1), and D_t is a dummy variable which is unity when the interventions were implemented and is zero otherwise. The model was again estimated by QMLE as discussed in section 2.

Table 2 reports results for when $\text{á}_1 = \text{ë}_1 = 0$, so that only the effects on mean returns are considered. In this specification the impact multiplier of the intervention is á_0 and the total multiplier is $\text{á}_0/(1 – \text{ë}_0)$. The estimation model for the intervention in the first column of table 2 indicates generally similar MA and FIGARCH parameter estimates as for table 1, and the estimated á_0 parameters are found to be very small but significant at the conventional levels, suggesting the central bank interventions exert a significant impact on the conditional mean of the exchange rate returns. However, the model implies the impact of the interventions of BOK resulted in an unexpected immediate depreciation (appreciation) of the Korean won (US dollar) following the intervention of 0.007% and a total long run depreciation of 0.58% for the interventions. This result seems to be similar to the well known “leaning against the wind” phenomenon presented by many previous empirical studies. One well known interpretation for this result is the bias of policy endogenity that is apparent with intervention in the more recent era, when the subsequent use of intervention as a policy tool is dependent on the state of the currency markets as pointed out by Baillie and Osterberg (1997a). Another interesting interpretation proposed by Beine, Benassy-Quere and Lecourt (2002) is that even though the initial effect of intervention may be successful in appreciating the currency during the first several hours, the market participants can further attack the currency to test the central bank to defend the currency so that it can cause the currency to depreciate at the end of the trading day. It should be interesting to investigate the effects of interventions at the intraday high frequency level in the future[6].

The table 3 shows the corresponding effects of the dynamic intervention variable on the conditional variance process. As in table 2, the estimated $\acute{a}_0$ and $\ddot{e}_0$ parameters for the conditional mean process are found to be very significant. And, the estimated $\acute{a}_1$ and $\ddot{e}_1$ parameters in the conditional variance process are also very small but significant at conventional levels. Hence, there is strong statistical evidence that the Korean intervention decreased trading activity, or uncertainty and market volatility about 0.0008% immediately following the interventions, implying that the interventions seem to be successful in making the disorderly market calm slightly. This is in sharp contrast to the results reported by Chang and Taylor (1998), Baillie and Osterberg (1997a,b), Goodhart and Hesse (1993) and Beine, Benassy-Quere and Lecourt (2002), who all note increases in volatility following intervention for the spot returns of DM-$ and Yen-$. And, the estimated long memory parameter (δ) is found to be almost the same as that from the model without the dummy variable. Thus, the long memory property of the volatility process appears not to be affected by the central bank intervention.

Furthermore, many theories of intervention have emphasized the effect of intervention on deviations from uncovered interest rate parity (UIP), rather than a direct effect on the spot rate. In particular, the risk premium model of Baillie and Osterberg (1997b) implies that intervention affects the risk premium term, $ñ_t$, in the model

$$(10) \qquad (s_{t+k} - s_t) - (f_t - s_t) = (s_{t+k} - f_t) = Ó_{j=1,k}\, è_j\, å_{t-j} + ñ_t ,$$

where f_t is the logarithm of the forward exchange rate for a k period maturity time. Hence the left hand side of equation (10) is the forward rate forecast error, $(s_{t+k} - f_t)$, the first term on the right hand side of the equation is a MA(k) process to reflect the fact that the forward rate forecast error may be autocorrelated to lag k, while $ñ_t$ is the risk premium and $å_t$ is a white noise process with zero mean, finite variance and is also serially uncorrelated.

For the test to the effects of the interventions on the risk premium during the crisis period, the forward rates (f_t) which are the 1-month Non-Deliverable Forward (NDF) exchange rates from July 2, 1997 to September 30, 1998, are matched with the future spot exchange rates (s_{t+k}) as suggested by Baillie and Osterberg (1997b). So, MA(22) process is used to estimate the forecast error. The QMLE of equation (10), with intervention variable, D_t, representing the risk premium term $ñ_t$, showed that the interventions of BOK during the crisis period do not Granger causes a risk premium, or excess returns from uncovered interest rate parity[7)].

4. Conclusion

This paper has examined the characteristics of the Korean Won-US Dollar daily exchange rates and the effects of Korean intervention on the foreign exchange market. The spot exchange returns exhibit the long memory properties in their absolute returns and conditional variances, which is the well documented feature of the foreign exchange market. The long memory volatility process, FIGARCH model is found to be an appropriate description of the volatility process of the daily W-$ returns. And the estimated long memory parameter is found to be more persistent especially during the crisis.

Most of central banks rely on intervention activity by believing that such activity is effective in either influencing the level of exchange rates or in reducing the volatility of the market. This paper has investigated the effectiveness of intervention conducted by the Bank of Korean which intended to achieve the two objectives; to support the Korean Won and to make the disorderly market calm during the currency crisis. For the purpose, this paper used a generalized FIGARCH model including a dynamic dummy variable to account for the intervention. The results find that the intervention can affect the level of the Won-$ exchange rate significantly but in the opposite direction, which is similar to the usual "leaning against the wind" phenomenon. The interventions by BOK are estimated to lead to an immediate depreciation of Korean Won 0.007%, and a total long run appreciation of 0.58%. But, the similar model reveals that the intervention had a slight effect on market volatility so that it reduced the market volatility about 0.0008% immediately after the interventions. Thus, this paper provides some mixed results about the effectiveness of interventions by BOK during the period of the crisis; i) the interventions were not successful in curtail the further depreciation of the exchange rates but ii) they were able to reduce the volatility of the market very slightly.

Furthermore, this paper shows that there is not any evidence that the Korean intervention Granger caused excess returns from uncovered interest rate parity, which may be associated with a time dependent risk premium, but is in contrast with evidence on the recent floating currency markets since 1973 presented by Baillie and Osterberg (1997b).

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[Footnotes]

1) The Asian crisis started in Thailand on July 2, 1997 when it changed its exchange rate system from the fixed pegged system to the floating system.

2) Tests of model diagnostics are performed by the application of the Box-Pierce portmanteau statistic on the standardized residuals. The standard portmanteau test statistic $Q_m = T\Sigma_{j=1,m} r_j^2$, where r_j is the j-th order sample autocorrelation from the residuals is known to have an asymptotic chi squared distribution with m-k degrees of freedom, where k is the number of parameters estimated in the conditional mean. Similar degrees of freedom adjustment are used for the portmanteau test statistic based on the squared standardized residuals when testing for omitted ARCH effects.

3) The results of GARCH(1,1) model is also available from the request to the author.

4) Park, Chung and Wang (2001) supposed the post-crisis started in September 1998 since the first round of financial restructuring was completed and the spot and forward rates have moved more tightly since that time.

5) The detail information for the intervention data is available by the request to the author.

6) Chang and Taylor (1998) used the intraday data for the analysis of the intervention of Bank of Japan.

7) The 1-month Non-Deliverable Forward (NDF) exchange rate data is from July 2, 1997 to February 23, 2000, and is provided by Prebon Yamine (HK) Ltd. The results is not reported to reserve the space but it is available by the request to the author.

Table 1(a) : Estimated MA(1)-FIGARCH(1,ä,1) Model for Daily W-$ Spot Returns

R_t = 100.Äln(S_t) = ì + $å_t$ + è$å_{t-1,}$

$å_t$ = z_t $ó_t$ where $z_{t,n}$ is i.i.d.(0,1) process

$ó_t^2$ = ù + â$ó_{t-1}^2$ + [1 - âL (1 - öL)(1 - L)^{ä}]$å_t^2$

	Whole period (7.2.' 97-12.31.' 01)	Post-crisis period (10.1.' 98-12.31.' 01)
Observations	1174	848
ì	-0.0042	-0.0104
	(0.0115)	(0.0114)
è	0.0789	0.0309
	(0.0404)	(0.0450)
ä	0.8312	0.5139
	(0.0805)	(0.1126)
ù	0.0045	0.0048
	(0.0031)	(0.0044)
â	0.7428	0.6138
	(0.0886)	(0.1764)
φ	0.3269	0.4262
	(0.0907)	(0.1764)
ln(L)	-954.604	-433.762
Skewness	0.309	0.034
Kurtosis	5.975	4.605
Q(20)	26.981	27.044
Q^2(20)	10.764	11.401
$W_{ä=0}$	106.602	20.835

Key : ln(L) is the value of the maximized log likelihood. The Q(20) and Q^2(20) are the Ljung-Box test statistics at 20 degrees of freedom based on the standardized residuals and squared standardized residuals. The sample skewness and kurtosis are based on the standardized residuals.

Table 1(b): Local Whittle Estimation for the Long Memory Parameter in the Absolute Daily W-$ Spot Returns

	Whole period (7.2.' 97-12.31.' 01)	Sub-period (10.1.' 98-12.31.' 01)
ä	0.8337 (0.0821)	0.5116 (0.0381)

Key: The Gaussian likelihood for an ARFIMA(0, ä, 0) model is maximized in the frequency domain from the first m low frequency ordinates. In the above, the value of m was T/16 and T/8 respectively where T = 1174 and 848 and is the sample size.

Table 2: Estimated MA(1)-FIGARCH(1,ä,0) Model for Daily W-$ Spot Returns with Dummy Variable in the Mean Process for Korea's Interventions during the Crisis.

y_t = 100*Äln(S_t) = ì + [á/(1 - ë L)] D_t + $å_t$ + è$å_{t-1}$

$å_t$ = z_t $ó_t$ where $z_{t,n}$ is i.i.d.(0,1) process

$ó_t^2$ = ù + â$ó_{t-1}^2$ + [1 - âL - (1 - L)^{ä}]$å_t^2$

where t=1,...1174 and D_t is one on intervention and zero otherwise.

Parameter	Estimated value
ì	-0.0107
	(0.0122)
á	0.0074
	(0.0030)
ë	0.9874
	(0.0423)
è	0.0815
	(0.0430)
ä	0.8480
	(0.0783)
ù	0.0044
	(0.0028)
â	0.7541
	(0.0871)
φ	0.3218
	(0.0890)
ln(L)	-952.365
Skewness	0.296
Kurtosis	5.959
Q(20)	21.127
Q^2(20)	9.951

Key : As for table 1(a).

Table 3 : Estimated MA(1)-FIGARCH(1,ä,0) Model for Daily W-$ Spot Returns with the Dummy Variables in the Mean process and the Variance Process for Korea's Interventions during the Crisis

y_t = ì + [á$_0$ /(1-ë$_0$L)] D_t + å$_t$ + èå$_{t-1}$

å$_t$ = z_t ó$_t$ where $z_{t,n}$ is i.i.d.(0,1) process

ó$_t^2$ = ù + [á$_1$ /(1-ë$_1$L)] D_t + âó$_{t-1}^2$ + [1 - âL - (1-L)^{ä}]å$_t^2$

where t=1,...1174 and D_t is one on intervention and zero otherwise.

Parameter	Estimated value
ì	-0.0108
	(0.0110)
á$_0$	0.0074
	(0.0035)
ë$_0$	0.9888
	(0.0348)
è	0.0817
	(0.0492)
ä	0.8473
	(0.0713)
ù	0.0045
	(0.0040)
á$_1$	-0.0008
	(0.0002)
ë$_1$	0.4396
	(0.1022)
â	0.7534
	(0.0680)
ϕ	0.3221
	(0.1211)
ln(L)	-905.104
Skewness	0.366
Kurtosis	7.150
Q(20)	21.478
Q^2(20)	14.258

Key : As for table 1(a).

Figure 1: Daily W-$ Spot Exchange Rate from July 2, 1997 through December 31, 2001.

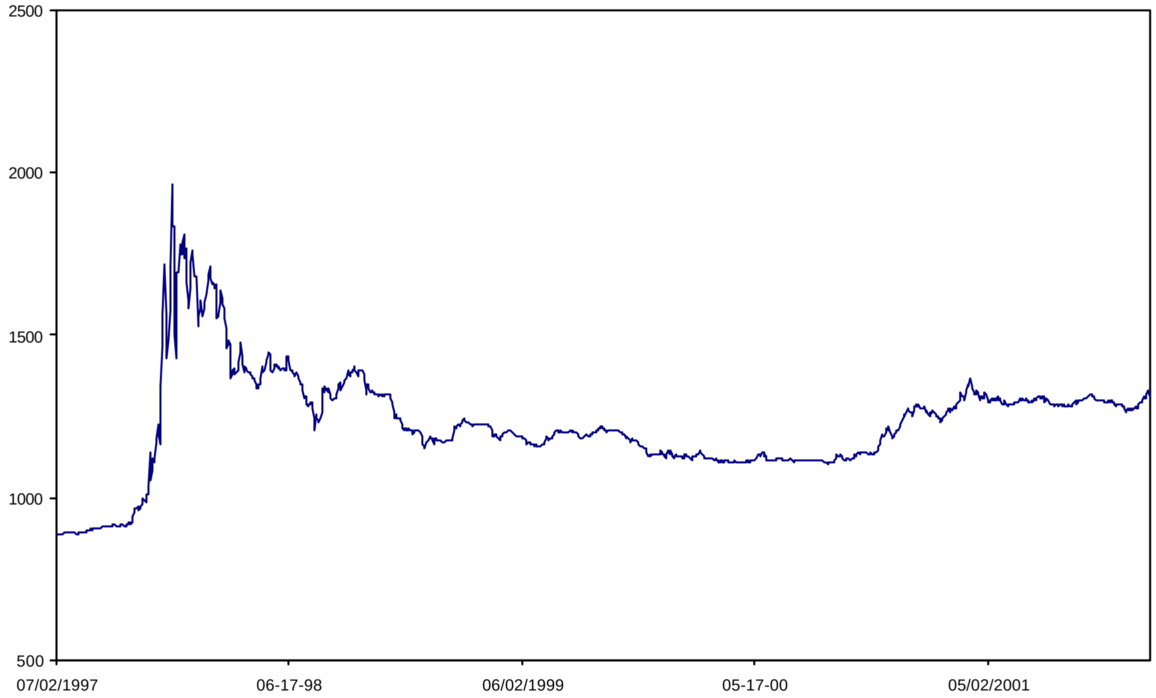

Figure 2: Correlograms of Daily W-$ Spot Returns

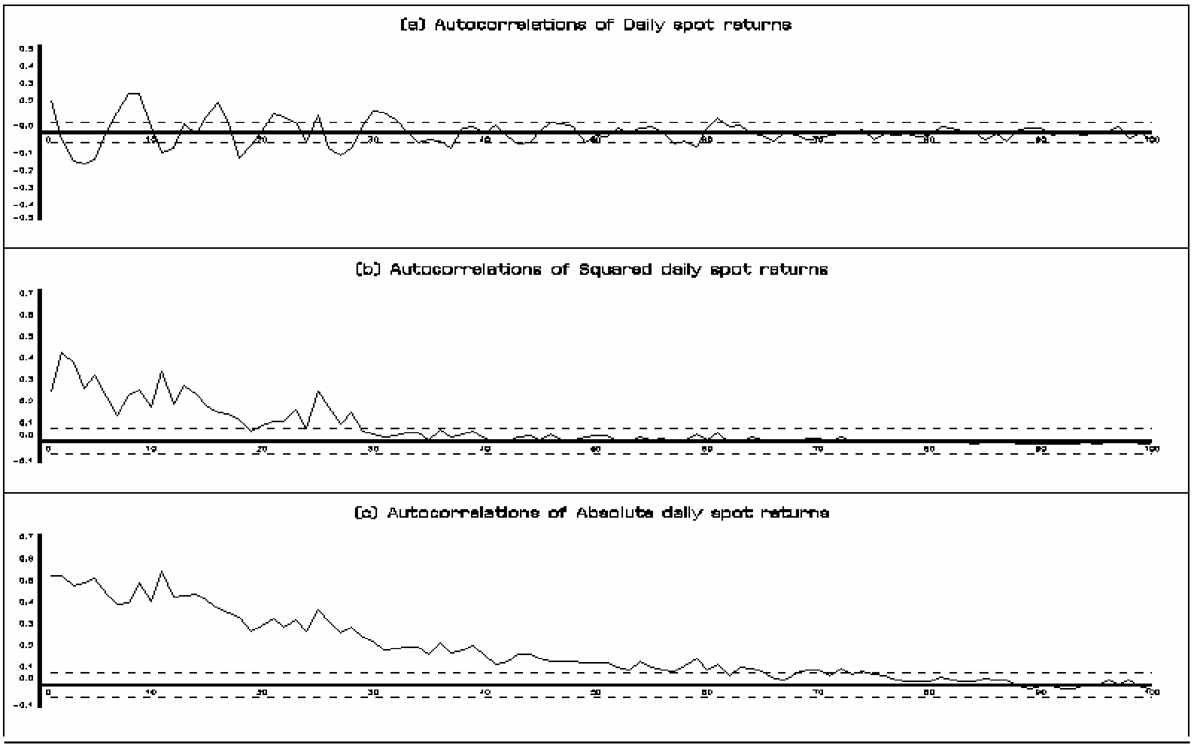

Figure 3: Correlograms of Standardized Residuals from MA(1)-FIGARCH (1,d,1) Model for Daily W-$ Spot Returns