Macroeconomic Shocks and Jumps in the Long Memory Models of Daily KRW-USD and KRW-JPY Foreign Exchange Rates

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This paper focuses on providing proper models for the daily Korean exchange rate dynamics which is subject to macroeconomic shocks. By investigating the daily KRW-USD and KRW-JPY exchange returns, this paper presents that the usual assumption of normal distribution is not appropriate in representing the daily Korean exchange returns due to the jumps which are related to the macroeconomic shocks of Korea, Japan and the U.S. Thus, this paper relies on the normal mixture distribution that allows for the jumps in the process of the daily Korean exchange returns. The normal mixture model with the Bernoulli distribution is found to perform quite well and to be important for the estimation of the long memory persistence in the daily Korean exchange return volatility. In particular, using the time-varying jump probability associated with the macroeconomic shocks of Korea, Japan and the U.S., this paper finds that the macroeconomic shocks induce jumps in the process of the daily exchange returns and appear to increase the long memory persistence in the daily Korean exchange return volatility.

Keywords: Daily Korean foreign exchange rates, FIGARCH, Normal mixture distribution, Long memory persistence, Macroeconomic shocks

JEL Classification: C22, F41

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I. Introduction

This paper is concerned with the intriguing features of the daily Korean exchange returns series of the U.S. Dollar (USD) and Japanese Yen (JPY) foreign exchange rates against the Korean Won (KRW) sampled form January 4, 1999 to December 31, 2002. In particular, this paper focuses on the two issues involved in the modeling of the daily Korean exchange returns. The first issue of this paper is to show that given the specification of both the conditional mean process and the conditional variance process of the daily Korean exchange returns, the occurrences of jumps appear to be responsible for the rejection of the normal distribution assumption which has been used for the estimation of traditional time series models such as ARMA (Auto Regressive Moving Average) models and ARCH (Auto Regressive Conditional Heteroskedasticity) models to explain the structural dynamics of foreign exchange rates. In turn, these jumps may be caused by specific economic and financial events like macroeconomic shocks in the foreign exchange markets concerning expected future flows of the commodity futures prices. These events may result in prices changes well above normal and might be better captured by jump process rather than normal innovations. Thus, the jumps have strong implications for the modeling the daily exchange returns. In order to account for the jumps, this paper adopts a normal mixture distribution, the Bernoulli-normal distribution that allows for the possibility of jumps. The mixture distribution is found to perform quite well and to be supported by the daily Korean exchange returns data.

The second issue of this paper is to provide economic explanations for the jumps occurred in the process of the daily Korean exchange returns. While explaining the short run dynamics of the daily Korean exchange returns, the basic normal mixture distribution model with a constant jump probability provides few economic and financial insights. Hence, based on the empirical literature on the effects of macroeconomic news on foreign exchange rates, this paper extends the basic normal mixture model by adopting the time-varying jump probability associated with the macroeconomic shocks of Korea, Japan and the U.S. This paper finds that the macroeconomic shocks originated from the macroeconomic fundamentals of Korea, Japan and the USA induce jumps in process of the daily Korea exchange returns and thus tend to increase the persistent volatility of the exchange returns.

The plan for the rest of this paper is as follows: section 2 describes the time series features of the daily KRW-USD and KRW-JPY exchange returns and presents the long memory FIGARCH model with the normal distribution retained for the basic analysis of the Korea daily exchange returns. Section 3 is devoted to the jumps in the process of the daily Korean exchange returns and describes the basic Bernoulli-normal distribution model with the constant jump probability. Then, it extends the basic mixture normal distribution model by using the time-varying jump probability associated with the macroeconomic shocks of Korea, Japan and the U.S. And section 4 finally provides a brief conclusion.

II. Long Memory Models with the Normal Distribution

This section is concerned with the sets of daily KRW-USD and KRW-JPY spot exchange rates sampled from January 4, 1999 to December 31, 2002 in which the Korean foreign exchange market is operating under a freely floating system. Each quotation consists of bid and ask prices aggregated from 5-minute exchange rates provided by Olsen & Associates of Zurich, consisting of Reuter FXFX quotes. The daily exchange returns are determined as the difference between the mid-points of the logarithmic bid and ask rates. The sample used in subsequent analysis contains a total of $T=1041$ observations. The daily returns of the KRW-USD and the KRW-JPY exchange rates are presented in Figures 1(a) and (b). In particular, the both returns are characterized by many large jumps followed by ostensibly random movement. The process of the KRW-USD exchange returns appear to be relatively more volatile with more significant jumps than that of the KRW-JPY returns. The jumps in the daily exchange returns may be closely related to macroeconomic news as presented by Andersen *et al.* (2003). In particular, Andersen *et al.* (2003) presented that the U.S. announcement shocks produce jumps in the conditional mean process of several foreign exchange rates so that the dynamics of the exchange rates is closely linked to macroeconomic fundamentals and the markets react to the jumps in asymmetric fashion.

Figures 2(a) and (b) plot the first 100 autocorrelations for the returns, the squared returns and the absolute returns of the daily spot returns of the KRW-USD and KRW-JPY exchange rates. While higher order autocorrelations are not significant at conventional levels, the first order

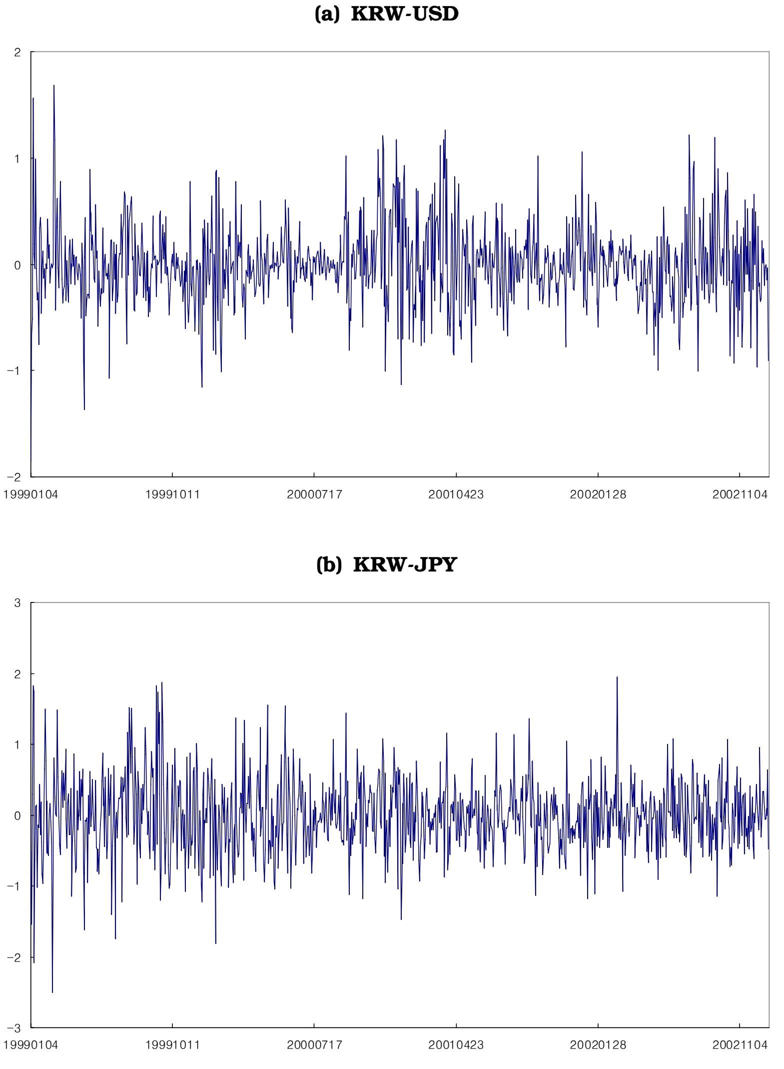
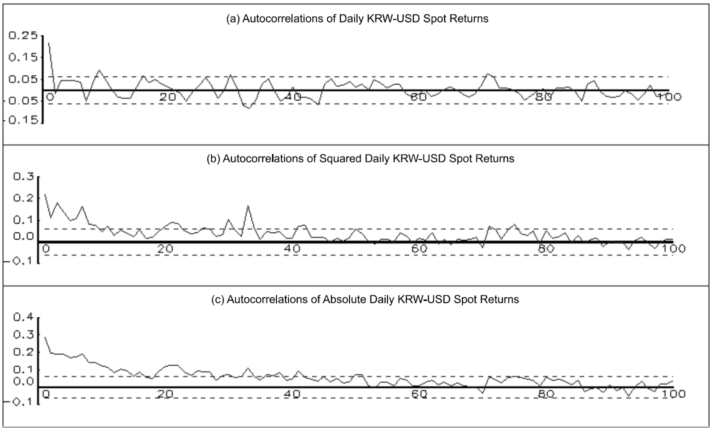


FIGURE 1
DAILY KOREAN EXCHANGE RETURNS

autocorrelations in the returns are large and positive for the two daily returns, which may be attributed to a combination of a small time varying risk premium, bid-ask bounce, and/or non-synchronous trading phenomena (Andersen and Bollerslev 1997; Baillie *et al.* 2000; Andersen

(a) KRW-USD



(b) KRW-JPY

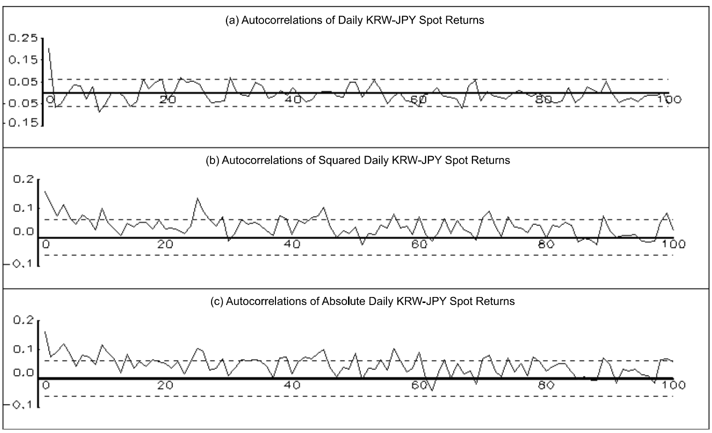


FIGURE 2
CORRELOGRAMS OF DAILY KOREAN EXCHANGE RETURNS

et al. 2003). And the autocorrelation functions of the squared and absolute returns of the KRW-USD and the KRW-JPY exchange rates decay very slowly at the hyperbolic rate, which is the typical feature of a long memory property. See Baillie (1996) for the details of the long memory property. These are in line with the findings of Andersen and Bollerslev (1997, 1998), Baillie *et al.* (2000), Beine *et al.* (2002) and Beine and Laurent (2003). In particular, the long memory property in the autocorrelations of the KRW-USD absolute returns tend to be more persistent than those of the KRW-JPY absolute returns.

The model that is consistent with these stylized facts is the ARMA (m, n)-FIGARCH (p, d, q) process,

$$y_t = 100^*[\ln(s_t) - \ln(s_{t-1})] = \mu + \varphi(L) y_{t-1} + \theta(L)\varepsilon_t \tag{1}$$

$$\varepsilon_t^2 = z_t \sigma_t \tag{2}$$

$$[1-\beta(L)]\sigma_t^2 = \omega + [1-\beta(L) - \phi(L)(1-L)^d]\varepsilon_t^2 \tag{3}$$

where s_t is the daily KRW-USD and KRW-JPY exchange rates, and z_t ~ *i.i.d.* (0, 1), μ and ω are scalar parameters, and $\beta(L)$ and $\phi(L)$ are polynomials in the lag operator to be defined later. The polynomials in the lag operator associated with the AR process and MA process are

$$\varphi(L) = 1 + \varphi_1 L + \varphi_2 L^2 + \cdots + \varphi_m L^m \text{ and } \theta(L) = 1 + \theta_1 L + \theta_2 L^2 + \cdots + \theta_n L^n.$$

And the parameter (d) represents the long memory parameter. The FIGARCH (Fractionally Integrated Generalized Auto Regressive Conditional Heteroskedasticity) model in Equation (3) is motivated by noting that the standard GARCH (Generalized Auto Regressive Conditional Heteroskedasticity) model of Bollerslev (1986) can be expressed as

$$\sigma_t^2 = \omega + \alpha(L)\varepsilon_t^2 + \beta(L)\sigma_t^2, \tag{4}$$

where the polynomials are $\alpha(L) \equiv \alpha_1 L + \alpha_2 L^2 + \cdots + \alpha_q L^q$, $\beta(L) \equiv \beta_1 L + \beta_2 L^2 + \cdots + \beta_p L^p$. The GARCH ($p$, q) process can also be expressed as the ARMA [max (p, q), p] process in squared innovations $[1-\alpha(L)-\beta(L)]\varepsilon_t^2 = \omega + [1-\beta(L)]v_t$ where $v_t \equiv \varepsilon_t^2 - \sigma_t^2$, and is a zero mean, serially uncorrelated process which has the interpretation of being the innovations in the conditional variance. Similarly, the FIGARCH (p, d, q) process can be written naturally as

$$\phi(L)(1-L)^d \varepsilon_t^2 = \omega + [1-\beta(L)]v_t, \tag{5}$$

where $\phi(L) = [1-\alpha(L)-\beta(L)]$ is a polynomial in the lag operator of order max (p, q). Equation (5) can be easily shown to transform to Equation (3), which is the standard representation for the conditional variance in the FIGARCH (p, d, q) process. Further details concerning the FIGARCH process can be found in Baillie *et al.* (1996). The parameter d characterizes the long memory property of hyperbolic decay in volatility because it allows for autocorrelations decaying at a slow hyperbolic rate. For $0<d<1$, the FIGARCH model implies a long memory behavior and is strictly stationary and ergodic (Baillie *et al.* 1996).

The above model (1), (2), and (3) is estimated for the daily Korean exchange returns of interest by maximizing the Gaussian log likelihood function,

$$\ln(L;\Theta)=-(\frac{T}{2})\ln(2\pi)-(\frac{1}{2})\sum_{t=1}^{T}[\ln(\sigma_{t,n}^2+\varepsilon_{t,n}^2\sigma_{t,n}^2] \qquad (6)$$

where Θ is a vector containing the unknown parameters to be estimated. However, it has long been recognized that most asset returns are not well represented by assuming z_t in Equation (2) is normally distributed. Even though sufficient conditions for the conditional variance to be strictly positive are given by Baillie *et al.* (1996), some of these sufficient conditions are overly restrictive as pointed by Nelson and Cao (1992). Thus, the estimation procedure in this paper allows ω to be negative following Beine and Laurent (2003). And the inference is usually based on the QMLE of Bollerslev and Wooldridge (1992), which is valid when z_t is non-Gaussian. Denoting the vector of parameter estimates obtained from maximizing (6) using a sample of T observations on Equations (1), (2), and (3) with z_t being non-normal by $\hat{\Theta}_T$, then the limiting distribution of $\hat{\Theta}_T$ is

$$T^{1/2}(\hat{\Theta}_T-\Theta_0)\rightarrow N[0,\ A(\Theta_0)^{-1}B(\Theta_0)A(\Theta_0)^{-1}], \qquad (7)$$

where $A(\bullet)$ and $B(\bullet)$ represent the Hessian and outer product gradient respectively, and Θ_0 denotes the vector of true parameter values. Equation (7) is used to calculate the robust standard errors that are reported in the subsequent results in this paper, with the Hessian and outer product gradient matrices being evaluated at the point $\hat{\Theta}_T$ for practical implementation.

This section of the paper represents an extensive analysis of the volatility properties of the daily Korean exchange returns using the FIGARCH model under the normal distribution. The orders of the ARMA and GARCH polynomials in the lag operator are chosen to be as parsimonious as possible but still provide an adequate representation of the autocorrelation structure of the daily Korean exchange returns data. Various tests for model specification of the daily exchange returns are performed. The Box-Pierce portmanteau statistics is applied to the standardized residuals. The standard portmanteau test statistic, $Q(m)=T(T+2)\sum_{j=1}^{m} r_j^2/(T-j)$, where r_j is the j'th order sample autocorrelation from the residuals, is known to have an asymptotic χ^2_{m-k} distribution, where k is the number of parameters estimated in the conditional mean. Similar degrees of freedom adjustments are used for the portmanteau test statistic based on the squared standardized residuals when testing for omitted conditional heteroscedasticity. And the sample skewness and kurtosis of the standardized residuals (m_3 and m_4) are also considered. The exact parametric specification of the model that best represents the degree of autocorrelation in the conditional mean and conditional variance of the daily Korean exchange returns are found to be the MA (1)-FIGARCH (1, d, 1) model.

Table 1 presents the results of applying the above model to the daily Korean exchange returns discussed earlier. The estimated MA (1)-FIGARCH (1, d, 1) model reported in Table 1 appears to describe the daily Korean exchange returns data rather well. All the models have significant MA (1) parameter estimates accounting for the large first order autocorrelation presented in Figure 2. The estimated long memory volatility parameters (d) are 0.62 and 0.26 for the daily KRW-USD and KRW-JPY exchange returns and are all statistically significant implying the significant long memory characteristics in the volatility of the daily Korean exchange returns. Thus, the hypotheses that $d=0$ (stationary GARCH) and also $d=1$ (integrated GARCH) are consistently rejected for the Korean exchange returns using standard significance levels. These results confirm the fact represented in Figure 2 that the daily Korean exchange returns contain the long memory volatility process and the long memory property in the KRW-USD returns is more significant than that in the KRW-JPY returns.

Table 1 also reports the robust Wald test statistics, denoted by W, for testing the null hypothesis of GARCH versus a FIGARCH data generating process. Under the null, W will have an asymptotic χ^2_1 distribution and, from Table 1, the GARCH model is rejected for every commodity at standard significance levels. This robust Wald test supports the fact that FIGARCH is superior to GARCH for modeling the conditional variances of the daily Korean exchange returns, which is consistent with the findings of Han (2003). Evidently, the long memory property is the characteristic feature of the daily Korean exchange returns, and the FIGARCH model represents a significant improvement

TABLE 1
MA (1)-FIGARCH (1, δ, 1) MODEL FOR THE DAILY KOREAN EXCHANGE RETURNS

	KRW-USD	KRW-JPY
μ	-0.0079	-0.0112
	(0.0104)	(0.0176)
θ	0.2404	0.2250
	(0.0367)	(0.0376)
d	0.6201	0.2600
	(0.1252)	(0.0882)
ω	0.0041	0.0180
	(0.0024)	(0.0173)
β	0.6283	0.5630
	(0.1116)	(0.2563)
φ	0.2450	0.3905
	(0.1169)	(0.2474)
$\ln(L)$	-333.691	-735.795
$m3$	0.056	0.142
$m4$	4.970	4.104
$W_{d=0}$	24.523	8.680

Note: QMLE asymptotic standard errors are in parentheses below corresponding parameter estimates. The quantity $\ln(L)$ is the value of the maximized log likelihood. The $m3$ and $m4$ represent the sample skewness and kurtosis of the standardized residuals. W is the robust Wald statistic for testing the GARCH specification against FIGARCH.

over GARCH.[1] Thus, the estimated MA-FIGARCH models appear to describe the daily returns data quite well so that it may be a satisfying starting point to analyze the nature of the underlying distributions in the daily Korean exchange returns.

And the Box-Pierce portmanteau test statistics for autocorrelation in the standardized and squared standard residuals are found to be 33.20 and 12.63 for the KRW-USD returns and 33.99 and 8.44 for the KRW-JPY returns showing that the models specified for the daily Korean

[1] Generally the IGARCH model implies the infinite persistence of a volatility shock and the stable GARCH model implies the shocks vanish exponentially over time. These features seem to be sharply contrary to the observed presence of the apparent long memory and temporal dependence in the autocorrelations of the squared and absolute returns of various financial data including exchange rates. The attraction of the FIGARCH process is that it is sufficiently flexible to allow for intermediate range of persistence.

returns do a good job of capturing the autocorrelations in the mean and volatility of the daily return series. In each case there is no evidence of additional autocorrelation in the standardized residuals or squared standardized residuals, indicating that the chosen model specification provides an adequate fit. The standardized residuals from the daily returns exhibit the usual features of non-normality of daily asset returns.

However, under the model with the normal distribution, the estimated excess kurtosis presented in Table 1 are 4.97 and 4.10 for the daily exchange returns of the KRW-USD and the KRW-JPY exchange rates respectively, which can reject the assumption of the normal distribution. The normal distribution seems to lead to excess kurtosis, and the excess kurtosis may be resulted from the jumps related to the macroeconomic news taken place in Korea, Japan and the USA during the sample period. These news concerning expected future flows of the exchange rates can result in price changes well above normal and might be better captured by jumps rather than normal innovations. These jumps might lead to the level and volatility outliers which can not be taken into account for by the simple normal distribution as Hotta and Tsay (1998) presented. Thus, the model with the normal distribution seems to be inappropriate to represent the daily Korean exchange returns series properly due to the jumps. One way to reconsider the model is to introduce jumps through the use of a normal mixture distribution.

III. Bernoulli-Normal Distribution Models

A. Constant jump probability

In order to account for the numerous jumps in the process of the daily Korean exchange returns, this paper employs the jump diffusion process proposed by Press (1967) assuming that the returns are drawn from a mixture of normal distributions, *i.e.,* a diffusion process combined with an additive jump process. Initially, Press (1967) proposed the jump diffusion model for stock prices under the assumption that the logarithm of the stock price follows a Brownian motion process on which i.i.d. normal distributed jumps are included. Jorion (1988) used a Press-type model to find some statistical evidence of jumps in the U.S.$-DM exchange rate for the post 1971 freely floating period. This jump diffusion model has subsequently been employed to model the

Exchange Rate Mechanism (ERM) of the European Monetary System (EMS) (Vlaar and Palm 1993; Baillie and Han 2001).[2]

This paper uses the Bernoulli distribution to model the stochastic jumps in the process of the daily Korean exchange returns series. The main characteristic of the Bernoulli process is that over a fixed time period (t), either an information impacts on the price or one relevant information arrival occurs with probability λ. While stochastic jumps are generally modelled by the Poisson distribution (Ball and Torous 1983; Hsieh 1989; Jorion 1988), the Bernoulli jump process appears to be practically more convenient in accounting for the jumps caused by new information arrivals than the Poisson distribution since the Bernoulli process is simpler in calculation without requiring the infinite sum and the truncation process required by the Poisson process. And Vlaar and Palm (1993) and Baillie and Han (2001) have shown that the results from the Poisson distribution model are generally not much different from those of the Bernoulli distribution model. Thus, this paper uses the Bernoulli jump process to account for the jumps and combines it with the FIGARCH model to analyze the impact of jumps on the long memory property in the conditional variance process of the daily Korean exchange returns series.

For the Bernoulli distribution, the jump intensity (λ) is forced in the (0, 1) interval and defined as $\lambda=[1+\exp(j)]^{-1}$. Thus, the jump probability is assumed to be constant over time. And the jump size is given by the random variable which is assumed to be NID$(\nu,\ \delta^2)$ where ν is the mean of the jump distribution and δ^2 captures the variance of the jump distribution. And the same FIGARCH model as in Section 2 is used for the long memory volatility process. Since the statistical and economic motivations for the jumps and the long memory property are quite different, this work chooses a model specification that accounts for the two features at the same time. The inclusion of the jump process

[2] The similar result can be obtained from GARCH model. This estimation result of GARCH model is quite in consistent with the findings of Vlarr and Palm (1993) and Baillie and Han (2001) who investigated the European exchange rates under the European Monetary System (EMS). In particular, Vlarr and Palm (1993) have presented evidence that the increased volatility resulting from jumps may be captured by the higher value of α and β in the GARCH model. And Baillie and Han (2001) considers a model in discrete time, providing a relatively simple formulation to investigate a target zone model, while Cheung and Tauchen (2001) and Ball and Roma (1993) favor continuous time models and have used jump diffusion process for the analysis of foreign exchange rates under the target zone model.

may reduce the influence of the conditional mean jumps on the MA-FIGARCH specification. Thus, the daily Korean exchange returns are still specified as following an MA (1) process, with the jump intensity of λ and the jump size of ν. The volatility process is the FIGARCH (1, d, 1) conditional variance model as developed in Section 2. This model can be rewritten as;

$$y_t = \mu + \lambda\nu + \varepsilon_t + b\varepsilon_t \tag{8}$$

$$\varepsilon_t \sim (1-\lambda)N(\lambda\nu,\ \delta^2) + \lambda N(\nu - \lambda\nu,\ \sigma_t^2 + \delta^2) \tag{9}$$

$$\sigma_t^2 = \omega + \beta\sigma_{t-1}^2 + [1 - \beta L - (1-\phi L)(1-L)^d]\varepsilon_t^2 \tag{10}$$

The log-likelihood function associated with this model takes the following form,

$$\ln(\xi) = -(\frac{T}{2})\ln(2\pi) - \sum_{t=1}^{T}\{[\frac{(1-\lambda)}{\sigma_t}]\times\exp[\frac{-(\varepsilon_t+\lambda\nu)^2}{2\sigma_t^2}] + [\frac{\lambda}{(\sigma_t^2+\delta^2)^{\frac{1}{2}}}]\times \exp[\frac{-(\varepsilon_t-(1-\lambda)\nu)^2}{2(\sigma_t^2+\delta^2)}]\} \tag{11}$$

It can be seen that δ^2 is the additional volatility related to jumps and the normal mixture distribution can account for the excess kurtosis. The form of the likelihood function for the Normal-Bernoulli jump processes is basically the same as that developed by Vlaar and Palm (1993) and Baillie and Han (2001). Asymptotic standard errors are calculated from the QMLE of Bollerslev and Wooldridge (1992) as in Section 2.

Table 2 reports the estimation results for the Bernoulli-normal distribution model. In general, the use of different distributions leads to quite different estimates even though the same MA-FIGARCH model is selected. As a whole the results confirm the appropriateness of MA-FIGARCH specification in capturing the dynamics of the daily Korean exchange returns. In particular, it can be found that the Bernoulli-normal distribution model contributes to decrease in the excess kurtosis of the daily returns. For the KRW-USD and the KRW-JPY returns, the estimated values of the kurtosis are found to be 2.03 and 2.57, which are smaller than the values under the normal distribution model in

TABLE 2

BERNOULLI-NORMAL DISTRIBUTION MODEL WITH A CONSTANT JUMP PROBABILITY FOR THE DAILY KOREAN EXCHANGE RETURNS

	KRW-USD	KRW-JPY
μ	-0.0112	-0.0666
	(0.0090)	(0.0450)
j	0.8583	1.0218
	(0.2921)	(0.5891)
ν	0.0068	0.1009
	(0.0382)	(0.0758)
δ^2	0.1620	0.2830
	(0.0334)	(0.1103)
θ	0.2461	0.2158
	(0.0338)	(0.0348)
d	0.0141	0.0625
	(0.0615)	(0.0388)
ω	-0.0003	-0.0001
	(0.0015)	(0.0004)
β	0.8062	0.9887
	(0.0477)	(0.0123)
φ	0.9230	0.9937
	(0.0281)	(0.0046)
$\ln(L)$	-292.407	-719.674
$m3$	0.014	0.134
$m4$	3.813	2.566

Note: The same as Table 1 except that a jump intensity of λ where $0<\lambda<1$ and $\lambda=[1+\exp(j)]^{-1}$, and is assumed to be exogenously constant over time. And the jump size is assumed to be NID $(\nu,\ \delta^2)$.

Section 2. And the LR tests for the daily returns confirm that the Bernoulli-normal distribution model outperforms the normal distribution model regardless the significance for each of the additional parameters (λ, ν, and δ^2). Thus, it seems to be adequate to introduce the possibility of jumps in the dynamics of the daily Korean exchange returns over the sample period.

The effects of the jumps on the daily exchange returns can be observed from the parameters estimates related to the jumps. It is seen that the jump probability (λ) can be found to be 0.30 and 0.27 for the KRW-USD and the KRW-JPY returns, which are calculated from the estimated parameters (j) of 0.86 and 1.02 for the KRW-USD and the KRW-JPY. Thus, the jump probability seems to be relatively larger in the KRW-USD returns than in the KRW-JPY returns, which is consistent with the findings in Figure 1. And while the estimate values of the jump mean (ν) are statistically insignificant, the estimates (δ^2) for additional volatility associated with the jumps are significant. On average, the jumps may not influence the conditional mean process of the daily Korean returns but they appear to significantly affect their conditional variance process by inducing the additional volatility.

Also, the estimates of the parameters (d), the degree of the long memory property in the volatility process, are found to be 0.014 and 0.063 for the daily KRW-USD returns and the KRW-JPY returns which are much lower than those with the normal mixture distribution than those found with the normal distribution. And they are all statistically insignificant indicating the rejection of the long memory property in the conditional variance process of the daily returns. This could be understandable given that the jumps, which otherwise may be spuriously associated with additional volatility, are fully accounted for in the normal mixture distribution. This is in line with the fact that the volatility processes of the daily Korean returns are associated with the jumps as specified by the estimate parameters (δ^2) previously. Thus the volatility persistence of the daily Korean returns could decrease when the jumps in the daily exchange returns are accounted for appropriately, which is quite similar to the results of Beine and Laurent (2003). They investigated the effects of central bank interventions on the daily DEM-USD and YEN-USD exchange returns by using the similar jump diffusion model and found that the central bank interventions induce jumps and increase the volatility of the exchange rates.

B. Time-varying jump probability associated with macroeconomic shocks

As stressed in the literature on market microstructure, the information flow is the major determinant of foreign exchange rate movements and the information can include both public and private components. With respect to the public information, the most common type is the scheduled announcements of macroeconomic indicators. Mostly, this kind of public information is officially forbidden to be announced until the scheduled release time so that there is no prior leakage of the information. Thus, the new public information of macroeconomic indicators reaches all participants in foreign exchange markets at the same time and then the exchange rates will adjust to incorporate the information.

The public news about macroeconomic indicators can cause jumps in foreign exchange rates given the specifications of the conditional mean and conditional variance process as pointed by Andersen *et al.* (2003).[3] In the light of the evidence on the existence of jumps in the process of the daily Korean exchange rates as presented in the previous section, this paper models the jumps and looks for an economic explanation for their existence. Since the jumps appear to be quite important in understanding the dynamics of the daily Korean exchange rates, modeling the jumps directly might give interesting additional insight into the mechanism of the daily Korean exchange rate dynamics. For the purpose, this paper adopts the time-varying jump probability which is associated with macroeconomic shocks of Korea, Japan and the U.S.

For the analysis, this paper uses the new data sets of the surveyed expectations and the actual realizations of the macroeconomic indicators for Korea, Japan and the USA provided by the International Money Market Service (MMS), which are similar to the datasets used in Andersen *et al.* (2003). By exploring the survey data on foreign exchange markets participants' expectations of the announcements for macroeconomic indicators of the three countries, this paper extracts the shock components of the indicators. Then this paper tests whether the macroeconomic shocks can explain the jumps occurred in the daily Korean exchange returns.

In order to calculate the macroeconomic shocks, this paper selects six major indicators among many macroeconomic indicators for each country of Korea, Japan and the USA, and then calculates the macroeconomic shocks to make the explanatory variables of the jump probability by using the expected and realized (announced) macroeconomic indicators.[4] The six major macroeconomic indicators for each country are the followings: for Korea, the indicators of trade balance, M2, unemployment, PPI, GDP and industrial products are sampled form 1999 to 2002. For Japan, the indicators of WPI, M2, trade balance,

[3] In addition to macroeconomic variables, the jumps in foreign exchange rates may be caused by other factors such as order flows (Dominguez and Panthaki 2005) and central bank's interventions (Beine and Laurent 2003).

[4] The major six macroeconomic indicators for each country of Korea, Japan and the USA are selected based on the results of Andersen *et al.* (2003). By using high frequency exchange rates of German Mark, British Pound, Japanese Yen, Swiss Franc and the Euro against U.S. dollar, they showed that the effects of the selected macroeconomic indicators are mostly significant on foreign exchange rates.

unemployment, and industrial products are used form 2000 to 2002. And for the USA, the indicators of industrial products, PPI, retail sales, trade balance, unemployment and GDP are selected form 1999 to 2002. Then, the macroeconomic shocks are calculated by the differences between the expected values and the realized values of the macroeconomic indicators ($k=1$, ..., 6) for each country is,

$$x_{t,k}=|(A_{t,k}-E_{t,k})/s_k| \quad (12)$$

where $A_{t,k}$ is the announced (realized) value of a macroeconomic indicator (k) released at day (t) in a country (i), $E_{t,k}$ is the market expected value of the macroeconomic indicator (k) as distilled in the MMS median forecast,[5] and s_k is the sample standard deviation of ($A_{t,k}-E_{t,k}$). Thus, the constant jump probability parameter (λ) in Eqs. (8)-(11) is replaced with the time varying jump probability (λ_t) given by the following logit specification,

$$\lambda_t=[1+\exp(\lambda_0+\Sigma_{k=1,6}\ \lambda_k x_{t,k})]^{-1} \quad (13)$$

where the $x_{t,k}$ is the macroeconomic shocks of each country expected to be related to the jump probability.

Table 3 shows that the estimated values of the mean sizes (ν) of the jumps associated with the macroeconomic shocks for the three countries are all statistically significant indicating that the macroeconomic shocks influence the conditional mean process of the daily returns. These results are in line with the findings of Beine *et al.* (2002) and Beine and Laurent (2003) that the jumps associated with central bank intervention tend to influence the level of exchange rates. Also, the estimation results in Table 3 present that the additional volatilities associated with the jumps (δ^2) are all positive and statistically significant for the two daily Korean returns implying that the jumps increase the exchange rate volatility. These results are consistent with the main

[5] For the MMS expectations data for macroeconomic indicators, the MMS has conducted a Friday telephone survey of about forty money managers, collected forecasts of all indicators to be released during the next week and reported the median forecasts from the survey. The sample period of the MMS data is during January 1999 through December 2002 for Korea and the U.S. and January 2000 through December 2002 for Japan. See Appendix A and B for the more detailed information about the MMS survey data and the macroeconomic shocks of Korea, Japan and the USA.

TABLE 3

BERNOULLI-NORMAL DISTRIBUTION MODEL WITH A TIME-VARYING JUMP PROBABILITY FOR THE DAILY KOREAN EXCHANGE RETURNS

1) The macroeconomic shocks of Korea and the U.S. on the KRW-USD returns

	Korea shocks	U.S. shocks
μ	-0.1275	-0.1244
	(0.0591)	(0.0808)
λ_0	-0.6824	-0.7592
	(0.2408)	(0.3798)
λ_1	-0.0041	-0.0098
	(0.1381)	(0.0768)
λ_2	0.3606	-0.0678
	(0.1210)	(0.0654)
λ_3	3.2598	0.0693
	(1.6259)	(0.0274)
λ_4	0.0627	0.3294
	(0.1046)	(0.3057)
λ_5	-0.1485	0.1184
	(0.1603)	(0.0534)
λ_6	-0.0392	0.4626
	(0.0817)	(0.4184)
ν	0.1464	0.1482
	(0.0662)	(0.0831)
δ^2	0.1499	0.1528
	(0.0267)	(0.0315)
θ	0.2442	0.2455
	(0.0344)	(0.0356)
d	0.0430	0.0223
	(0.0349)	(0.0502)
ω	0.0022	0.0011
	(0.0023)	(0.0022)
β	0.7490	0.7682
	(0.0448)	(0.0549)
φ	0.9087	0.9101
	(0.0272)	(0.0308)
$\ln(L)$	-290.563	-287.197
$m3$	0.302	0.307
$m4$	2.882	2.925

Note: The same as Table 1 and Table 2-(1) except the parameters, λ_1, λ_2, λ_3, λ_4, λ_5, and λ_6 represent the estimated values for the macroeconomic shocks of trade balance, M2, unemployment, PPI, GDP and industrial production for Korea, and of industrial production, PPI, retail sales, trade balance, unemployment and GDP for the U.S.

2) The macroeconomic shocks of Korea and Japan on the KRW-JPY returns

	Korea shocks	Japan shocks
μ	-1.1650	-1.5427
	(0.4460)	(0.5156)
λ_0	-0.2631	-0.1868
	(0.1385)	(0.1181)
λ_1	0.0451	0.8048
	(0.0319)	(0.2379)
λ_2	0.0326	0.0519
	(0.0495)	(0.0734)
λ_3	0.2820	0.0169
	(0.0791)	(0.0121)
λ_4	-0.0362	0.3815
	(0.0502)	(0.1279)
λ_5	0.1269	-0.0056
	(0.0789)	(0.0156)
λ_6	0.0923	0.0142
	(0.0599)	(0.0191)
ν	1.1190	1.4594
	(0.3982)	(0.4558)
δ^2	0.1780	0.1655
	(0.0422)	(0.0417)
θ	0.2248	0.2153
	(0.0364)	(0.0346)
d	0.0188	0.0100
	(0.0252)	(0.0180)
ω	-0.0022	-0.0047
	(0.0032)	(0.0045)
β	0.9850	0.9782
	(0.0130)	(0.0145)
φ	0.9917	0.9874
	(0.0060)	(0.0094)
$\ln(L)$	-714.430	-713.583
$m3$	0.450	0.350
$m4$	-1.488	-0.097

Note: i) The same as Table 1 except that a jump intensity of λ_t where $0<\lambda<1$ and $\lambda_t=[1+\exp(\lambda_0+\sum_{k=1,6}\lambda_i x_t^k)]^{-1}$ and is specified by the Bernoulli process. And the jump size is assumed to be NID (ν, δ^2). ii) The parameters, λ_1, λ_2, λ_3, λ_4, λ_5, and λ_6 represent the estimated values for the macroeconomic shocks of trade balance, M2, unemployment, PPI, GDP and industrial production for Korea, and of WPI, M2+CD, trade balance, unemployment, retail sales and industrial production for Japan.

conclusions reported by the literature investigated the effects of macroeconomic fundamentals on exchange rate volatility. Thus, the results confirm that the macroeconomic shocks are associated with the jumps observed in the dynamics of the daily Korean exchange returns.

The estimated parameters (d) of the long memory property are again found to be all statistically insignificant for the two daily Korean exchange returns suggesting that the long memory property in the conditional variance process becomes insignificant once the jumps are modeled appropriately. This supports the strong interaction between the jumps and the long memory volatility persistence of the daily Korean exchange rates. Interestingly the estimated values of the excess kurtosis are found generally to be lower than those of the constant jump probability model indicating that the use of the time varying jump probability can improve the fit of the model. And the LR test statistics are found to be 1.85 and 4.79 for the KRW-USD returns and 5.25 and 6.09 for the KRW-JPY returns indicating the time-varying jump probability model outperforms the constant jump probability model. Thus, the use of the time-varying jump probability explained by macroeconomic shocks allows us to provide an economic interpretation of these jumps and support the evidence that the macroeconomic shock increase the exchange rate volatility.

Table 3 also represents the estimation results from the model with the time varying jump probability for the daily returns series of the KRW-USD and the KRW-JPY exchange rates. The shocks of unemployment originated from Korea, the U.S. and Japan are found to significantly influence the jump probability in the two Korean exchange returns. And the shocks of M2 in Korea are significant for the KRW-USD returns. Similarly the U.S. shocks of retail sales and the Japanese shocks of WPI significantly affect the jump probability of the KRW-USD returns and the KRW-JPY returns respectively. The general pattern is one of very quick adjustment in exchange rates characterized by a jump immediately following the shocks. This is because the good growth shocks in the economy tends to produce the appreciation of its currency and conversely. This is very consistent with a variety of models of exchange rate determination including monetary models. For example, the macroeconomic shocks of Korea tends to appreciate (if it is positive) or depreciate (if negative) the Korean won against the U.S. dollar and the Japanese Yen so that the shocks tend to increase the jump probability.

IV. Conclusions

This paper considers four years of the daily KRW-USD and KRW-JPY exchange rates over the periods of 1999 through 2002. Special attention is devoted to model the jumps and the long memory property appropriately in the MLE estimation procedure.

Initially, this paper uses the FIGARCH model of Baillie *et al.* (1996) under the normality assumption to consider the daily Korean exchange returns series. But, the estimated excess kurtosis is found to be large for the two daily Korean exchange returns indicating the rejection of the normal distribution in representing the daily Korean exchange returns. The occurrences of the jumps in the process of the daily exchange returns appear to be responsible for the rejection of the normal distribution assumption. Thus, this paper uses the normal mixture distribution, the Bernoulli-normal distribution to account for the jumps more appropriately. Even though the normal mixture model with the constant jump probability provides the strong evidence of the jumps in the daily Korean exchange returns but can not give any economic and financial insights. Hence, the normal mixture model adopts the time varying jump probability associated with macroeconomic shocks of Korea, Japan and the U.S. This model shows that the significant part of the jumps in the daily Korean exchange returns are closely related to macroeconomic shocks of Korea, Japan and the USA.

Main findings of this paper are; i) that the long memory property in the conditional variance decreases when accounting for the jumps appropriately observed in the daily exchange rate dynamics, ii) that the use of the time-varying jump probability associated with the macroeconomic shocks provides the economic interpretation of the jumps and improves the fit of the model for the daily returns, iii) that the results of this paper support the evidence that the macroeconomic shock increase the exchange rate volatility, in line with the findings of the previous empirical literature, and iv) that the model with the time-varying jump probability may be an alternative model to long memory models with a normal distribution or to other models excluding outliers.

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Appendix A: Examples of the MMS Data for macroeconomic indicators of Korea, Japan and the USA

1) The Korean Data from 1999 to 2002

Macroeconomic variable	Median expectations	Actual realizations	Date of release
Trade Balance (billion)	4.0	4.2	01-02-99
M2 (billion)	25	22	01-07-99
Unemployment Rate (%)	7.9	7.8	01-22-99
PPI (%)	-0.9	-1.8	02-01-99
GDP (%)	4.0	4.6	03-23-99
Industrial Production (%)	2.0	4.7	01-26-99

2) The Japanese Data from 2000 to 2002

Macroeconomic variable	Median expectations	Actual realizations	Date of release
WPI (%)	-0.4	-0.6	08-07-00
M2+CD (%)	2.0	1.9	08-08-00
Trade Balance (billion)	1343	723	08-09-00
Unemployment Rate (%)	4.7	4.7	08-28-00
Retail Sales (%)	-4.9	-4.4	08-29-00
Industrial Production (%)	1.9	0.3	08-10-00

3) The U.S. Data from 1999 to 2002

Macroeconomic variable	Median expectations	Actual realizations	Date of release
Industrial Production (%)	0.0	0.2	03-16-99
PPI (%)	0.1	0.5	02-18-99
Retail Sales (%)	0.3	0.2	02-11-99
Trade Balance (billion)	-15.0	-17.0	03-18-99
Unemployment Rate (%)	4.4	4.3	02-05-99
GDP (%)	3.45	4.5	04-30-99

Appendix B: Basics for the macroeconomic shocks of Korea, Japan and the USA

1) The Korean shocks from 1999 to 2002

Macroeconomic shocks	Total numbers	Means	Standard Deviations
Trade Balance	25	5.21	3.89
M2	32	3.80	4.37
Unemployment Rate	26	3.14	5.62
PPI	31	4.54	3.68
GDP	10	6.38	8.41
Industrial Production	30	4.53	3.86

2) The Japanese shocks from 2000 to 2002

Macroeconomic shocks	Total numbers	Means	Standard Deviations
WPI	12	4.82	6.78
M2+CD	17	2.93	6.31
Trade Balance	22	4.31	4.24
Unemployment Rate	14	3.31	6.96
Retail Sales	22	4.73	3.80
Industrial Production	21	4.70	4.04

3) The U.S. shocks from 1999 to 2002

Macroeconomic shocks	Total numbers	Means	Standard Deviations
Industrial Production	39	4.46	2.64
PPI	37	4.31	3.14
Retail Sales	44	2.53	4.20
Trade Balance	46	3.55	3.20
Unemployment Rate	33	5.05	2.51
GDP	14	7.96	3.44

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