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A STUDY ON THE COMPARATIVE ANALYSIS OF VOLATILITY BETWEEN WON-DOLLAR EXCHANGE RATES AND WON-YEN EXCHANGE RATES ACCORDING TO THE MUTATION OF FINANCIAL ENVIRONMENTS

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The Asymmetry Effect of Volatility

Abstract. The major purpose of this study is to analyze comparatively the characteristics of this volatility between won-dollar exchange rates and won-yen exchange rates according to the mutation of financial environments. This study uses the GARCH model which considers the time-varying and clustering property and T-GARCH Model which additionally considers the asymmetry property to estimate the volatility of exchange rates. This study uses the daily exchange rate data from February 1990 when Korea introduces the Market Average Exchange Rate System to August 2008. Estimation results show that there are the ARCH effects, the GARCH effects on the exchange rates. Also, the median lag shows that the volatility of won/dollar exchange rate is bigger than won/yen exchange rate. Also there is a trend that median lag increased after the Asian Currency Crisis. In addition, there are differences in exchange rate volatility periodically and country-by-country. In conclusion, these characteristics of the exchange rates are helpful to make the foreign exchange reserves policy more efficiently.

INTRODUCTION

The major purpose of this study is to analyse comparatively the characteristics of this volatility between won-dollar exchange rates and won-yen exchange rates according to the mutation of financial environments. Recently, financial environment are rapidly changed, and the uncertainty of economy are increased. In this economic condition, it is important to analyze the property of the foreign exchange market according to the change of the financial market for the country that has high foreign dependent like Korea.

When examine the Korea's economic condition history, it has been experienced many crisis. changed many financial infrastructures. In specific, in the middle of 1970s, the world's economy rapidly changed because of the innovation of the finance by US. And Korea implemented the market average exchange rate system to cope with economic situations. After that, there is asian financial crisis in 1997 and Korea implemented freely fluctuating exchange rate system in earnest. During the asian financial crisis, Korea restructured firms, financial institutions. Finally Korea overcame the crisis and made a remarkable growth. However, global financial crisis broke out in 2008 because of the bankrupt of the Lehman Brothers. In consequence of the crisis, world's economy and the same Korea experience the deep recession.

Therefore, for analyzing the property of volatility of the each exchange rate according to the change of the financial condition, this study divides the data into 4 periods. The period 1 is the term from March 1990 when the market average exchange rate system was implemented to 1997. The period 2 is the term when Asian financial crisis occur in 1997. The term of after the crisis to before the global financial crisis is defined the period 3. Lastly, the term of the global financial crisis in progress to present is the period 4. Using this data, this study estimates the GARCH and asymmetric GARCH model about exchange rate for different periods. Next, based on the estimation results, this study calculate and compare the median lag and the size of the volatility for different periods and each country. Finally, this study draws political implications about the foreign exchange reserves.

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MODEL

Specification of the Model

(1) ARCH LM Test

This study conducted LM Test for checking the existence of the time-varying effect, in other worlds, ARCH effect, on won-dollar exchange rate and won-yen exchange rate, All variables are taken logarithm. Here is the results of the LM test, and there are ARCH effects on each exchange rate.

		Obs*R-squared	Prob. Chi-Square(1)
Won-Dollar Exchange Rate	**1**	2262.08*** (2265*099)	0.00
	2	286.14*** (321*0.89)	0.00
	3	2418.21*** (2433*0.99)	0.00
	4	1684.56*** (1737*0.96)	0.00
	Whole	6618.17*** (6759*0.97)	0.00
Won-Yen Exchange Rate	**1**	2254.52*** (2265*0.99)	0.00
	2	273.74*** (321*0.85)	0.00
	3	2407.77*** (2433*0.98)	0.00
	4	1711.54*** (1737*0.98)	0.00
	Whole	6734.12*** (6759*0.99)	0.00

※ critical value : 1% 6.635

Unit Root Test

Variables			**X**	**ln(X)**	**△ln(X)**
Won-dollar Exchange rate			-2.570001*	-2.435016	-29.48583***
Won-Yen Exchange rate			-1.606332	-1.384484	-29.46544***
※ Significance level 1%, 5% 10% ***, **, *					
※ Critical Value	1%	-3.433910			
	5%	-2.862999			
	10%	-2.567594			

To examine the time-series properties of individual series, a preliminary procedure for the stationarity property of the concerned variables is followed using the augmented Dickey-Fuller (ADF) unit root test. The result shown in Table 2. The optimal lags for the ADF test are chosen with the Schwarz information criterion (SIC). They indicate that all the variables at the first difference are stationary. In case of won-dollar exchange rate, the variable is stable at their level at the 10% significance level, but the variable is stable at the first difference at 1% significance level. Therefore, this study used all the variables at first difference.

Volatility Measure

Exchange rate volatility is not directly observable, but various statistical measures have been used in previous studies. Although previous studies have tended to use one measure of exchange-rate volatility by assuming that the error term has a constant variance in estimating the exchange rate process, the present study uses the most recent measure by considering time-varying and asymmetric responses to the volatility of exchange rates.

The exchange rate volatility is specified as time-varying volatility by the LM test and preceding researches. Therefore, in this study, exchange rate is measured by recently developed methods using the conditional variance in the exchange rate model as a GARCH-type process (Engle, 1982 ; Bollerslev, 1986) and its extensions with asymmetric GARCH models. Unlike traditional measures of exchange rate volatility which may potentially ignore information on the stochastic processes by which exchange rates are generated (Jensen, 1989), GARCH-type models capture the time-varying conditional variance as a parameter generated from a time-series model of the conditional mean and variance, which can be very useful in describing volatility clustering (Onafowora and Owoye, 2008). GARCH models cansuccessfully model the relationship between the variances and means (Bollerslev, 1986; Engle et al., 1987; Bollerslev et al., 1992). Following Bollerslev (1986), the present study specifies exchange rate risk ar time-varying exchange rate volatility constructed through the GARCH process so that a larger estimated conditional variance can indicate a higher level of risk. Further, in terms of exchange rates, previous studies have observed that there exist asymmetric effects of exchange rate risk with dynamic conditional variances (Engle and Ng, 1993; Tse and Tsui, 2002). To consider the possibility of asymmetric effects in the volatility measure, the present study employs the following recently developed asymmetric GARCH models: threshold ARCH (TARCH).

In this study, conventional GARCH is used for the first measure of exchange rate volatility. Following the specification from Engle and Granger (1987) and Onafowora and Owoye (2008), the GARCH (1, 1) model based on an autoregressive model of order 1 in the real exchange rate is employed :

$$ER_t = \beta_0 + \beta_1 ER_{t-1} + \epsilon_t$$
$$where\ \epsilon_t \sim N(0, V_t^2) \quad \text{………………………. (1)}$$

$$V_t^2 = \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \alpha_2 V_{t-1}^2 \quad \text{……………………. (2)}$$

$$(\alpha_0 > 0, \alpha_1 \geq 0, \alpha_2 \geq 0, \alpha_1 + \alpha_2 < 1) \quad \text{……….. (3)}$$

where ER_t is real exchange rate at time t, ϵ is the white-noise error term and V_t^2 is conditional variance. The conditional variance equation (2) is a function of three terms: the long-ream mean (α_0), the lag of the squared residual from the mean equation (ϵ_{t-1} : the ARCH term), and the previous period's forecast error variance (V_{t-1}^2 : the GARCH term). The conditional variance equation is estimated with Eqaution (1), and the predicted value of V_t^2 provides a measure for the volatility of the Korea won against the U.S. dollar and the Japanese yen. Equation (3) is the sufficient condition that conditional variance has positive value and the ARCH process is stable.

The second measure is the asymmetric GARCH model, a new complementary volatility measure considering the asymmetric responses to exchange rate volatility. The most interesting feature not addressed by ARCH-type models is the asymmetric effect discovered by Black (1976) and confirmed by subsequent findings such as Nelson (1991) and Engle and Ng (1993), among others. The asymmetric effect of the conditional variance means that exchange rates are negatively correlated with changes in exchange rate volatility, such that this volatility tends to increase in response to bad news and decrease in response to good news. However, ARCH-type models with simple parameterization cannot capture this important data feature. The recently proposed methods for capturing such asymmetric effects are threshold ARCH (T-GARCH) by Glosten et al. (1993). Thus, in this study, a pure GARCH – Equation (2) and asymmetric GARCH model are estimated to capture the asymmetry of the conditional variance in exchange rate volatility.

$$V_t^2 = \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \gamma d_{t-1} \epsilon_{t-1}^2 + \alpha_2 V_{t-1}^2 \quad \text{……………………… (4)}$$

($d_t = 1$ if $\epsilon_t < 0$, and 0 if $\epsilon_t > 0$, $\gamma > 0$) ………………… (5)

In addition, this study divides the total data set into four sections. To analyze the exchange rate volatility according to the change of the financial condition, the conditional variance equation of GARCH model - Equation(2) and T-GARCH model – Equation (4) includes period dummy variables in the estimation using total data set

$$V_t^2 = \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \alpha_2 V_{t-1}^2 + \alpha_3 d_{2t} + \alpha_4 d_{3t} + \alpha_5 d_{4t} \quad \text{……………………………. (6)}$$

$$V_t^2 = \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \gamma d_{t-1} \epsilon_{t-1}^2 + \alpha_2 V_{t-1}^2 + \alpha_3 d_{2t} + \alpha_4 d_{3t} + \alpha_5 d_{4t} \quad \text{…………… (7)}$$

d_{2t} : the 2nd period(1997.10.24. ~ 1999.1.25. : 1, the rest : 0)

d_{3t} : the 3rd period(1999.1.26. ~ 2008.9.14. .: 1, the rest : 0)

d_{4t} : the 4th period(2008.9.15. ~ 2015.8.31. : 1 the rest : 0)

DATA

The data on won-dollar and won-yen exchange rate are drawn from the Bank of Korea's statistics. The data are of daily frequency and spanned from March 1990 to August 2015. And the size of the data set is totally 6,760. This study using this data divided into four periods. The first period included term from after the introduction of the market average exchange rate system (1990.3.2.) to just before the occurrence of the Asian Financial Crisis (1997.10.23.). The second period includes the term when Asian Financial Crisis occurred (1997.10.24.) to finished (1999.1.25.). And this study sets the third period that includes term from after the end of the Asian Financial crisis(1999.1.26.) to just before the global financial crisis(2008.9.14.). Lastly, the fourth period included the term when the bankrupt of the Lehman Brothers occurred(2008.9.15) to present(2015.8.31.).

<Figure 1> shows that the trend of the won-dollar and won-yen exchange rate during the financial environment changing period(1990.3.2.~2015.8.31.) After the Asian Financial Crisis(the 2nd period), the strong won against dollar and yen lasted. And during the Global financial crisis, the weak won against dollar and yen stood out.

Figure 1: The trend of the won-dollar and won-yen exchange rate during the financial environment changing period(1990.3.2.~2015.8.31.)

TABLE 3

SPECIFICALLY SHOWS THE BASIC STATISTICS OF ALL THE VARIABLES. THE EXCHANGE RATE OF WON-DOLLAR AND WON-YEN.

	Period 1		Period 2		Period 3		Period 4		Whole Period	
	₩-$	₩- ¥	₩-$	₩- ¥	₩-$	₩- ¥	₩-$	₩- ¥	₩-$	₩- ¥
Mean	0.0002	0.0001	0.0009	0.0008	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001
Median	0.0000	0.0000	0.0008	0.0000	-0.0002	0.0000	-0.0004	-0.0003	-0.0001	0.0000
Max.	0.0400	0.0121	0.1629	0.1809	0.0456	0.0332	0.0708	0.0714	0.1629	0.1809
Min.	-0.0401	-0.0223	-0.2010	-0.2012	-0.0458	-0.0306	-0.1084	-0.0920	-0.2010	-0.2012
Std. Dev.	0.0066	0.0014	0.0297	0.0281	0.0073	0.0042	0.0110	0.0081	0.0103	0.0078
Skewness	0.2536	-0.5762	-0.1863	-0.0077	0.1748	0.3022	-0.3188	-0.7244	-0.1861	-0.0567
Kurtosis	7.0932	40.9474	16.9891	22.0794	5.4803	9.4997	17.9301	30.9670	61.7876	182.9244
J-B Stat.	1605	136026	2627	4884	636	4322	16172	56793	973329	9116986

Prob.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Obs.	2265	2265	322	322	2434	2434	1738	1738	6759	6759

According to the Table 3, the standard deviation of won-dollar exchange rate volatility in whole period(0.0103) is bigger than that in second period when the asian financial crisis occurs(0.0297) and in forth period when the global financial crisis outbreaks. This means that the won-dollar exchange rate volatility is increased during the second and forth period. Thus, won-dollar exchange rate has bigger volatility during the asian financial crisis(period 2) according to the change of the size of the standard deviation.

In addition, the case of won-yen exchange rate, the standard deviation of the whole period(0.0078) is smaller than of the second period(0.0281) and the forth period(0.0081). The won-yen exchange rate volatility is increased because of the change of the financial environment in this period. won-yen exchange rate also has bigger volatility during the asian financial crisis(period 2) according to the change of the size of the standard deviation.

In the empirical analysis, variables are taken logarithm and first integration for stabilization. Because the first differential coefficient taken logarithm is extremely small, this study used 100-times variables. These does not affect the econometric analysis such as t-value.

ESTIMATION RESULTS AND INTERPRETATION

Estimation Results of the Exchange Rate Volatility

The estimation results for the GARCH(1, 1) model of won-dollar and won-yen exchange rate are shown in Table 4 and Table 5. According to the estimation results, all cases satisfied the condition $\alpha_0 > 0, \alpha_1 \geq 0, \alpha_2 \geq 0, \alpha_1 + \alpha_2 < 1$ $\alpha_1 + \alpha_2 < 1$. Thai is, this satisfies the sufficient condition for stable ARCH process.

	Period 1 (90.3.2– 97.10,23)	**Period 2 (97.10.24-99.1.25)**	**Period 3 (99.1.26-08.9.14)**	**Period 4 (08.9.15-09.2.28**	**Whole (90.3.2-15.8.31)**
			Average Equation		
C	0.003551* (0.002074)	-0.057745 (0.060986)	-0.015490** (0.007001)	-0.019318* (0.010366)	0.001346 (0.001929)
ER_{t-1}	0.246623*** (0.025959)	0.288624*** (0.067600)	0.130734*** (0.022347)	0.106843*** (0.025208)	0.171810*** (0.013470)
			Conditional Variance Equation		
C	0.000857*** (5.89E-0.5)	0.060632** (0.022192)	0.012406*** (0.001642)	0.002607*** (0.000657)	0.000643*** (3.70E-0.5)
ϵ^2_{t-1}	0.219835*** (0.010081)	0.405806*** (0.050264)	0.205177*** (0.016331)	0.090555*** (0.009161)	0.173247*** (0.005127)
V^2_{t-1}	0.764541*** (0.009922)	0.546206*** (0.042650)	0.731058*** (0.021595)	0.902892*** (0.007942)	0.812108*** (0.005578)
d_{2t}	-	-	-	-	0.052625*** (0.008495)
d_{3t}	-	-	-	-	0.005124*** (0.000455)
d_{4t}	-	-	-	-	0.007514*** (0.001086)
logL	1706.707	-564.5896	-1014.130	-1344.291	-1260.837

※ ( ) : Standard Deviation

※ Critical Value 1%, 5% 10% ***, **, *

	Period 1 (90.3.2– 97.10,23)	**Period 2 (97.10.24-99.1.25)**	**Period 3 (99.1.26-08.9.14)**	**Period 4 (08.9.15-09.2.28**	**Whole (90.3.2-15.8.31)**
Average Equation					
C	0.022005* (0.012970)	-0.132540 (0.091761)	-0.020962 (0.013769)	-0.036608** (0.018170)	-0.005450 (0.008230)
ER_{t-1}	-0.037521* (0.021917)	0.131651* (0.068554)	-0.189524*** (0.021645)	0.032304 (0.025793)	-0.063224*** (0.013065)
Conditional Variance Equation					
C	0.006824*** (0.001206)	0.298632*** (0.095496)	0.017675*** (0.003186)	0.010726*** (0.002517)	0.012928*** (0.001320)
ϵ_{t-1}^2	0.039789*** (0.004366)	0.317505*** (0.067394)	0.069651*** (0.006530)	0.068012*** (0.008259)	0.072896*** (0.004035)
V_{t-1}^2	0.945159*** (0.005760)	0.0674105*** (0.045686)	0.896888*** (0.009534)	0.920363*** (0.008493)	0.902948*** (0.005007)
d_{2t}	-	-	-	-	0.122323*** (0.010319)
d_{3t}	-	-	-	-	0.001389 (0.001138)
d_{4t}	-	-	-	-	0.005602*** (0.001422)
logL	-2187.016	-682.8362	-2553.441	2230.972	-7741.258

※ ( ) : Standard Deviation

※ Critical value 1%, 5% 10% ***, **, *

In terms of the won-dollar exchange rate in whole period, dummy variables(d_{2t}, d_{3t}, d_{4t}) for analyzing the exchange rate volatility according to the change of the financial condition are significant at the 1% level. The size of the volatility during the asian financial crisis(0.0526) is bigger than that during the global financial crisis(0.0075). The third period's volatility(0.0051) is the smallest.

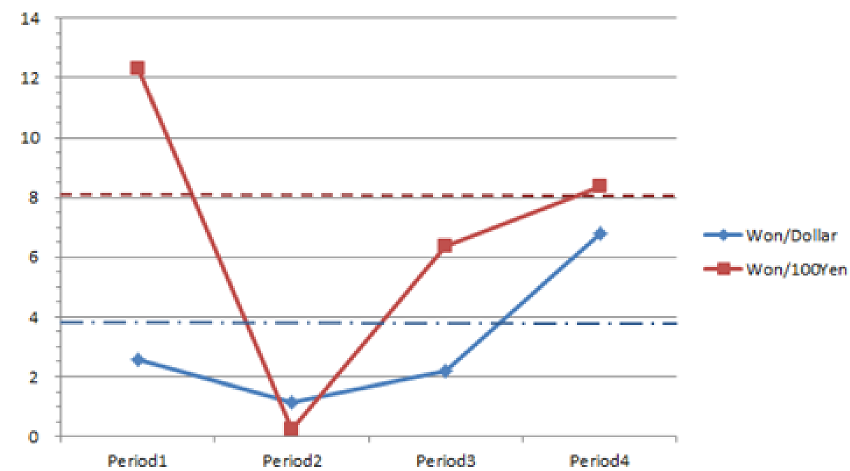
Next, in case of the won-yen exchange rate, dummy variables for the 2nd and 4th period are significant at 1% level. The size of the volatility during the asian financial crisis(0.1223) is bigger than that during the global financial crisis(0.0056). However, the third period's dummy variable is not significant at any level.

Comparing between the won-dollar and won-yen exchange rate volatility, won-yen exchange rate volatility is bigger than won-dollar exchange rate volatility both during the Asian Financial Crisis and Global Financial Crisis.

Median Lag

For calculate the durability of the shock(news) in the conditional variance equation, this study uses the 'Median Lag". In the conditional variance equation, if $\alpha_2 < 1$, it is possible to show like $\sigma_t^2 = \frac{\alpha_0}{1-\alpha_2} + \alpha_1 \sum_{s=0}^{\infty} \alpha_2^s \epsilon_{t-s-1}^2$. Therefor, Median Lag is the T that satisfied this equation ' $\alpha_1 \sum_{s=0}^{t-1} \frac{\alpha_2^s}{\alpha_1} \sum_{s=0}^{\infty} \alpha_2^s = (1-\alpha_2^T) = \frac{1}{2}$, . Then, $T = \frac{-\log 2}{\log \alpha_2}$. Jong sun, Kim(2009).

	Period 1 (90.3.2– 97.10,23)	**Period 2 (97.10.24-99.1.25)**	**Period 3 (99.1.26-08.9.14)**	**Period 4 (08.9.15-09.2.28**	**Whole (90.3.2-15.8.31)**
won-dollar	2.5817	1.1462	2.2126	6.7853	3.9046
won-yen	12.2894	0.2570	6.3694	8.3525	7.0446



The median lag calculated by the estimation results of the won-dollar and won-yen exchange rate volatility is shown Table 6 and Figure 2. In Figure 2, the red dotted line and blue dotted line are the won-yen and won-dollar exchange rate's median lag of the whole period .

In case of the whole period, the won-dollar exchange rate's durability is decreased after 3.9046 days and the won-yen exchange rate's durability is decreased after 7.0446 days. These means that the recovery time of the won-dollar exchange rate is relatively shorter than won-yen exchange rate when there is a shock in foreign exchange market. Also, there is the trend that median lag is increasing after the Asian Financial Crisis(the 2nd period). This implies that the durability of the shock is increasing.

Analysis of the Asymmetry of the Exchange Rate Volatility

This study estimated the T-GARCH model using equation(7) to analyze the asymmetry of the exchange rate volatility. The estimation results shown in Table 7. Shown in Table 7, estimation results of the T-GARCH(1, 1) model that using dummy variables for the whole period shows that coefficients of the won-dollar exchange rate and won-yen exchange rate are each –0.1412 and –0.0527. These coefficients are significant at 1% level, but these have negative value. So, there is no asymmetry in exchange rate volatility. In other words, there is no difference whether negative shocks or positive shocks.

Meanwhile, there is some differences between the estimation results of the T-GARCh model and the GARCH model. The estimation results of the T-GARCH model is equal with the results of the GARCH model that the won-yen exchange rate volatility is bigger than won-dollar during the Asian Financial Crisis. However, during the Global Financial Crisis, the estimation of the T-GARCH model shows that won-dollar exchange rate volatility is bigger though the GARCH model shows that won-yen exchange rate volatility is bigger.

	won-dollar (1990.3.2. - 2015.8.31.)	**won-yen (1990.3.2. - 2015.8.31.)**
	Average Equation	
C	0.005900*** (0.001980)	0.003536 (0.008422)
ER_{t-1}	0.173790*** (0.013182)	-0.064412*** (0.012847)
	Conditional Variance Equation	
C	0.000553*** (3.65E-05)	0.012185*** (0.001234)
ϵ_{t-1}^2	0.223462*** (0.007124)	0.091803*** (0.005433)

$d_{t-1}\epsilon_{t-1}^2$	-0.141211*** (0.007971)	-0.052769*** (0.005695)
V_{t-1}^2	0.828123*** (0.005413)	0.909764*** (0.004879)
d_{2t}	0.051122*** (0.008413)	0.107494*** (0.010114)
d_{3t}	0.005552*** (0.000429)	0.001653 (0.001058)
d_{4t}	0.008058*** (0.000970)	0.006665*** (0.001342)
logL	-1204.376	-7695.733

※ ( ) : Standard Deviation

※ Critical Value 1%, 5% 10% ***, **, *

CONCLUSION

This study examines how the exchange rate volatility changes according to the change of the financial environment by comparing properties of the won-dollar and won-yen exchange rate volatility. The whole analysis period is daily data from 1990 to 2015, and grouped into four time periods 1990~1997, 1997~1999, 1999~2008 and 2008~2015 by the financial environment change. The GARCH and T-GARCH model is specified and estimated for different periods based on the data. In case of the whole period, this study uses the models added periodical dummy variables.

As a result, there are three implications of the comparison analysis of the won-dollar and won-yen exchange rate volatility. First, in the estimation result of the GARCH model for the whole period, the median lag, the volatility shock's durability, is 3.90 in case of the won-dollar exchange rate and 7.09 in case of the won-yen exchange rate. This means that the volatility shock has a effect during 3.90days in case of the won-dollar exchange rate and 7.09days in case of the won-yen exchange rate. In other words, when there are exchange rate shocks, the won-dollar exchange rate volatility as compared with the won-yen exchange rate take short time to return to stable state of the foreign exchange market. In addition, analyses for each period were found that there is the growing trend of median lag to all variables after the Asian Financial Crisis. This means that durability of the shock is increased following the rapid economic change.

Next, the estimation results of the GARCH model to analyze the exchange rate volatility according to the financial condition change shows that the won-dollar exchange rate volatility is smaller than the won-yen exchange rate volatility in the 2nd period when the Asian Financial Crisis break out and the 4th period when the Global Financial crisis occurs. However, the estimation results of the T-GRARCH model shows that won-yen exchange rate volatility is smaller than won-dollar during Global Financial Crisis(the 4th period). In other words, the estimation of the GARCH and T-GARCH model shows the contradictory results about the comparative analysis between the won-dollar and the won-yen exchange rate. However, the size of the difference is slight. Therefore, dollar and yen have a similar status as the safety currency, and this implies that it is possible to increase efficiency of the existing dollar-oriented foreign exchange reserves management policy through diversification of currency reserves.

Lastly, according to the exchange rate volatility asymmetry analysis, there is no asymmetry in the won-dollar and won-yen exchange rate. Because asymmetry coefficients are statistically significant but they have negative values. This means that the exchange rate volatility changes similarly whether the positive or negative shock.

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