ECONOMIC PAPERS
Vol. 4, No. 1, May 2001
THE BANK OF KOREA

Exchange Rate Movement Before and After Free Floating: Efficiency and Technical Trading Profitability

Sangdai Ryoo*

This paper examines whether the Korean foreign exchange market has become efficient following introduction of the free-floating exchange rate regime by comparing exchange rate movements, autocorrelation coefficients and profitabilities of technical analysis before and after the free-floating regime.

While the exchange rate can be closely approximated by a random walk after free floating, the sample autocorrelations of daily changes in the exchange rate are still large. Moreover, several technical analyses of the foreign exchange market are more profitable than before. These facts imply that the foreign exchange market is not efficient yet. That is, the exchange rate still moves in trends despite the increased exchange rate volatility after introduction of the free-floating system. This finding is supported by profitabilities in different filter sizes of filter rule.

JEL Classification Number : F31

Key words : Leptokurtic, Random Walk, Foreign Exchange Market Efficiency, Interest Rate Parity, Technical Analysis

Ⅰ. Introduction

The Korean foreign exchange market has been changing in light of increased transaction turnover and exchange rate volatility since Korea shifted to a free-floating exchange rate system and began opening the domestic market to foreign

* Economist, International Finance Research Team, International Department, the Bank of Korea (E-mail: sryoo@bok.or.kr).
The author is grateful to seminar participants and three anonymous referees for their helpful comments and suggestions.

investors in late 1997. Even though sufficient data has not been accumulated yet, it is important to understand the exchange rate behavior in some possible ways because it forms the basis for discussion and analysis of other exchange rate-related issues. For example, the time-series behavior of the exchange rate has implications on the question of market efficiency. Also, the distributional property of exchange rates, in part, determines the riskiness of the exchange market and the validity of statistical inference in empirical work. In particular, understanding market efficiency becomes more essential to Korea because market efficiency is necessary to deepen its foreign exchange market and integrate its economy into the international market.

In the almost 30 years since the collapse of Bretton Woods in 1973, data has been accumulated on the exchange rates between the major currencies. Discussions are currently ongoing about the stylized facts on these rates. Many recent empirical investigations have unanimously uncovered the following facts concerning high frequency exchange rate data: The exchange rates are closely approximated by a random walk,[1] the distribution of exchange rate changes is in general leptokurtic[2] and the autocorrelations of exchange rate changes are generally small.[3]

While the notion of foreign exchange market efficiency has also been tested and retested with the changing environments surrounding the foreign exchange market, the present literature is still far from conclusive and inconsistencies abound. The standard approach to testing foreign exchange market efficiency has been to examine the efficiency of the forward market, that is, to test whether forward rates are unbiased and efficient estimators of the future spot rate. While many of these results go against foreign exchange market efficiency(Longworth(1981)), there is a possibility that the existence of transaction costs and risk premiums makes forward rates different from unbiased estimators of the future spot rate, despite the existence of an efficient foreign exchange market(Hodrick (1989)). With the new approaches to testing efficiency, such as cointegration and the application to the foreign exchange market(Crowder(1994), Engel(1996)), there has been no consensus surrounding the foreign exchange market efficiency, mainly due to the risk premium.

Conceptually, the autocorrelation of exchange rate changes may also be used to

---

1) Meese and Rogoff(1983) show that none of the exchange rate models outperforms the simple random walk based on a comparison of root mean square errors(RMSEs).

2) Since leptokurtic distribution was first observed in the context of the foreign exchange market, by Giddy and Dufey(1975), on the basis of the daily exchange rate changes, there have been many studies and hypotheses on the degree of leptokurtosis for short-run exchange rate changes and the distributional characteristics.

3) While the sample autocorrelations of monthly exchange rate changes are statistically significant, those of both weekly and daily exchange rate changes are not significant in general(Hsieh(1988), Levich and Thomas(1991), Takagi(1988), Ito(1993)).

test the spot market efficiency. There are contentions, however, that traditional serial correlation tests are flawed because they seek to determine only if a stable linear relationship exists between successive exchange rate movements(Hsieh (1989)).

To test foreign exchange market efficiency, many researchers have instead chosen to examine directly the success that actual technical models would have had in generating profitable buy and sell signals if such models had been followed in the past(Levich and Thomas(1991), Silber(1994), Neely(1997)). There are also a number of problems associated with inferring the degree of market efficiency from the apparent profitability of these trading rules, including data problems and problems inherent in measuring the costs and risks associated with foreign exchange transactions. In the end, foreign exchange market efficiency is to be tested both using various methods and by examining the microstructure of the market such as asymmetric information and the role of risk.

While some research in Korea has studied the forward market efficiency of developed countries,[4] there have been few studies on the market efficiency of Korean foreign exchange.[5] This reflects the fact that the data accumulated in Korea is not sufficient for the forward market efficiency to be tested, using the regular regression method. In fact, the history of Korea's forward market is not long and turnover in the market is still very limited.

Thus, the main purpose of this paper is to examine, based on the limited data, the changes in the Korean foreign exchange market after the introduction of the free-floating regime by focusing on efficiency.

This paper is organized as follows. The next section outlines the exchange rate movements and analyzes the time-series characteristic of the exchange rate before and after the free-floating regime. In Section Ⅲ, the general facts about foreign exchange market efficiency are reviewed and an efficiency test is conducted using simple autocorrelation analysis. In Section Ⅳ, the profitability of technical trading rules and foreign exchange market efficiency are examined. Finally, Section Ⅴ concludes the paper with a summary of the empirical analysis on the foreign exchange market after introduction of the free-floating regime, and draws some policy implications.

4) Mo and Kee(1996).

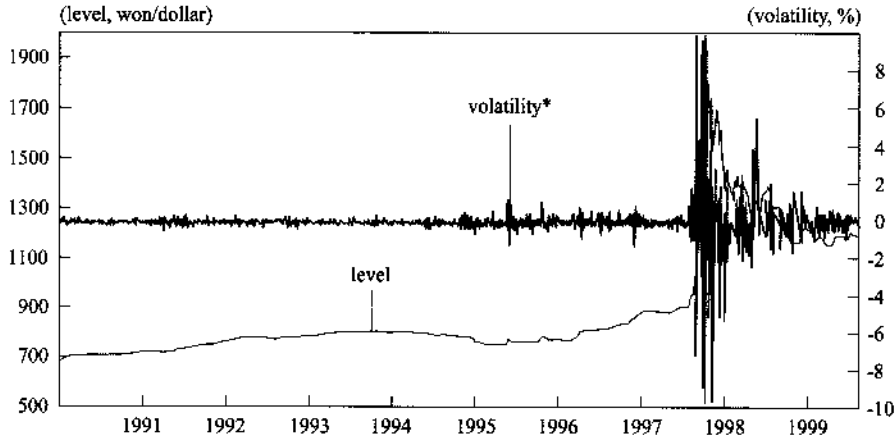
5) Ha(1996) and Park and Song(1999).

Ⅱ. Exchange Rate Behavior and its Time-series Properties

1. Exchange Rate Behavior

In March 1990, Korea replaced the multiple-basket pegged exchange rate system by a market average exchange rate system(MARS) in which the interbank spot rate was allowed to move within an upper and a lower limit around each day's basic exchange rate. The daily fluctuation limits for the interbank exchange rate had been enlarged and finally abolished in December 1997, which means Korea's exchange rate system was shifted to a free-floating system.[6] The exchange rate behavior during the post-MARS era reflects these evolutions of the exchange rate regime in Korea. Both the exchange rate level and volatility, in general, continued to grow gradually until the financial crisis set in. Volatility worsened and the exchange rate experienced large fluctuations during the short period following the introduction of the free-floating system, excluding the crisis period.

[Figure 1] Level and Volatility of Exchange Rate



Note: Volatility is a daily change which is shown not to be much different from monthly standard deviation or variance modelled from ARCH.

6) The daily fluctuation limits for the interbank exchange rate were changed as follows: 0.4% (1990.3) → 0.6% (1991.9) → 0.8% (1992.7) → 1.0% (1993.10) → 1.5% (1994.11) → 2.25% (1995.12) → 10.0% (1997.11) enlarged → abolished (1997.12)

2. Distributional Properties

It is well known that the empirical distribution of short-run changes in asset prices, such as stock prices and exchange rates, are often too 'peaked' and too 'fat-tailed' to fit the normal distribution, or so-called leptokurtic.[7] One quantitative measure of a leptokurtic distributional characteristic can be given by kurtosis.[8] A distribution that is too 'peaked' and too 'fat-tailed' relative to the normal has a value of kurtosis greater than 3 ; such a distribution is usually called leptokurtic.

[Table 1] presents basic statistical measures of daily changes in the spot exchange rate of the Korean won to the U.S. dollar. It is noted that although the distributions were almost always symmetrical to 0, all values of kurtosis were significantly greater than 3, indicating that the distributions were more leptokurtic than the normal distribution would imply.

[Table 1] Basic Statistics of Daily Exchange Rate Changes

	Whole Period	Before Free Floating		After Free Floating	
		(1996.1.3 -1997.12.15)	Excluding Crisis Period[1]	(1997.12.16 -1999.9.30)	Excluding Crisis Period[1]
Sample Size	927	481	450	445	376
Mean	0.000	0.001	0.000	-0.001	0.000
Standard Deviation	0.016	0.012	0.003	0.020	0.008
Kurtosis[2]	46.01**	42.29**	10.37**	35.59**	8.66**

Notes: 1) The crisis period is from 1997.11.1 to 1998.3.31.
2) A value of kurtosis greater than 3 implies that the distribution is leptokuttic, and *(**) indicates the kurtosis is significantly greater than 3 at 5%(1%) significance.

7) Some hypotheses have been advanced to account for the leptokurtosis of empirical distributions of the asset price changes. They may include some kind of mixed distribution, time varying parameters and volatile and choppy markets where large price changes are more often than not likely to be followed by large changes with the sign reversed, and most small changes are positively correlated.

8) Kurtosis(a_4) is defined as follows:

$$a_4 = \frac{m_4}{\sigma^4}$$

where m_4 is the fourth moment around the mean and σ is the standard deviation. The kurtosis obtained from the actual sample becomes bigger as the relative frequencies of observations deviated greatly from the mean are higher.

It is also worthwhile to note that the standard deviation has increased after the free-floating regime, while the kurtosis has decreased.[9] This implies that the free-floating system has made the exchange rate more volatile on the whole, but the relative frequencies of observations that deviated greatly from the mean has decreased after the free-floating regime.

3. Random Walk

Much attention has been paid to some stylized facts about exchange rates after the collapse of Bretton Woods in 1973, including that the exchange rate follows a random walk. Many empirical investigations have shown that the exchange rates between major currencies are closely approximated by a random walk, which implies that exchange rate cannot be predicted by any macro-variables or structural model(Meese and Rogoff(1983)).

While the daily exchange rate of the Korean won to the U.S. dollar is shown to be stationary before free floating, it is closely approximated by a random walk after free floating(see [Table 2]). Hence, the use of high frequency exchange rate data in empirical works involving structural modeling should be made with care.

[Table 2] Unit Root Tests of Daily Exchange Rates

		Whole Period	Before Free Floating (1996.1.3 -1997.12.15)	Before Free Floating Excluding Crisis Period	After Free Floating (1997.12.16 -1999.9.30)	After Free Floating Excluding Crisis Period
Dickey-Fuller Test	t-statistics	-1.6	5.4**	1.8**	-2.2	-1.5
	F-statistics	1.5	17.6**	9.4**	3.2*	1.5
Augmented DF Test		-1.2	5.3**	1.7**	-3.3**	-1.9
Phillips-Ferron Test		-1.5	4.9**	1.5*	-1.9	-1.7

Note: *(**) indicates that the null hypothesis of random walk is rejected significantly at the 5%(1%) level.

9) It can be shown that the kurtosis has significantly decreased after free floating by using the fact that the kurtosis is asymptotically normal with a mean of 3 and variance of 24/T as the number of observations increases.

Ⅲ. Foreign Exchange Market Efficiency

1. Tests of Foreign Exchange Market Efficiency

In general, an efficient capital market is defined as a market in which prices fully reflect all available information and, consequently, investors cannot systematically earn an "unusual" profit on the basis of information available in the market.[10] In an efficient market, participants usually take a passive trading strategy on the market price and derivatives evolve as means of hedging risk. Efficiency helps many unprivileged players to participate in the market with their own risk-return profiles, and thus contributes to opening local markets to the international market.[11]

Market efficiency is conceptually a joint hypothesis of the price predictability by an equilibrium market model and the rationality of expectation, which brings about some practical difficulties in testing market efficiency. As for the foreign exchange market, empirical testing of efficiency involves more complications because there is no satisfactory equilibrium model for the exchange rate and the riskiness of speculation in the foreign exchange market needs more examination. In the end, testing foreign exchange market efficiency is focused on examining the existence of exploitable profit opportunities rather than on the equality of actual exchange rate and the predicted exchange rate by an equilibrium model.

Efficiency of the foreign exchange market is usually realized depending on two conditions: covered interest rate parity that riskless arbitrage yields no profit and forward market efficiency in which the forward exchange rate incorporates all available information about the expected future spot rate.

- covered interest rate parity $\quad f_{t,t+1} - e_t = i_t - i_t^* + u_{t+1} \quad (1)$
- forward market efficiency $\quad f_{t,t+1} = E_t e_{t+1} + r_{t+1} \quad (2)$

$$\Rightarrow \quad E_t e_{t+1} - e_t = i_t - i_t^* + u_{t+1} - r_{t+1} \quad (3)$$

10) This definition of market efficiency, more specifically, breaks down into three operational types of efficiency, mainly according to what constitutes "available" information: weak form efficiency, semi-strong form efficiency and strong form efficiency. Weak form efficiency postulates that investors cannot earn abnormal returns from examining past price data, and semi-strong form efficiency also goes on to include publicly available information as part of the information set available to the market. Both forms of efficiency require that the asset price should be the market's best prediction based on all publicly available information. Strong form efficiency states that investors cannot earn unusual returns even with some proprietary information because of regulations on public announcement and insider dealing.

11) The openness policy improves foreign exchange market efficiency in the other direction.

where $f_{t,t+1}$ is the one-period ahead forward exchange rate at t, e_t is the spot exchange rate at t, E_t is a mathematical expectations operator based on the set of information available at t, i_t is the domestic interest rate, i_t^* is the foreign interest rate, u_t is the random deviation, and r_t is the risk premium, and all terms except interest rates are expressed in logarithm.

Equation (3) states that the interest rate differential arbitrage yields no profit[12] since the exchange rate fully reflects all the information including risk premium if u_t is a zero-mean white noise.

From equations (1)~(3), the following equations, (1)'~(3)', are derived for the estimation, in which the parameter restriction of $\alpha = 0$ and $\beta = 1$ or the stationarity of the residual series are empirically tested to examine foreign exchange market efficiency.[13]

$$f_{t,t+1} - e_t = \alpha + \beta(i_t - i_t^*) + \varepsilon_{t+1} \quad (1)'$$

$$e_{t+1} = \alpha + \beta f_{t,t+1} + \varepsilon_{t+1} \quad (2)'$$

$$\Delta e_{t+1} = \alpha + \beta(i_t - i_t^*) + \varepsilon_{t+1} \quad (3)'$$

This type of efficiency test not only has some procedural problems in relation to the classical test of unit roots in the residuals,[14] but also it is not immune to the riskiness of speculation in the foreign exchange market. That is, the form of risk may render the above equations to not hold in spite of market efficiency and it is not easy to evaluate the riskiness of some assets in different countries.

It is even more difficult to apply this type of test to Korea's market because the forward rate data is not sufficient in both quantity and quality, and, there is little information on the risk and risk premium.[15]

2. Autocorrelations of Changes in Exchange Rate

First, the spot market efficiency is conceptually examined using the sample

12) Equation (3) amounts to uncovered interest parity in case that r_t is 0.

13) Specifically, $\alpha = 0$ and $\beta = 1$ is what we refer to as semi-strong form of efficiency, and the stationarity of the residual corresponds to a weak form of efficiency.

14) This type of efficiency has recently been further developed and reviewed with some progress in unit-root test methodology(Dutt and Ghosh(1999)).

15) Park and Song(1999) note that there has been no regulation on the offshore non-deliverable forward (NDF) markets for Korean won against the U.S. dollar and that foreigners have freely participated in those markets. They show that there exists some bias between the spot rate and NDF forward rate, which implies market inefficiency.

autocorrelations of exchange rate change on the basis of weak form efficiency.[16] Most empirical studies have found that the sample autocorrelations of the changes in the exchange rate between major currencies are small and not significant, irrespective of the lag length.

The sample autocorrelations of the changes in daily exchange rate for Korean won to the U.S. dollar are shown to remain large even after the free-floating regime (see [Table 3]). This suggests the possibility that the foreign exchange market is still inefficient and the exchange rate moves in trends after free floating. With the crisis period included, the sample autocorrelations are significantly large over the whole lags regardless of free floating. This is mainly due to the fact that the exchange rate continues to rise for a while and then decline during the crisis period, thus forming the trends.

It is noted that the method of examining market efficiency through the autocorrelations requires the less justifiable assumption that the nominal interest differential is constant, and the autocorrelation test is basically based only on the linear relationship between exchange rate movements.[17] In the following section, market efficiency is examined by analyzing directly whether the use of technical trading rules would have yielded significant risk-adjusted returns had they been rigidly followed in the past.

[Table 3] Autocorrelations of Daily Exchange Rate Changes[1)]

Lag	Whole Period	Before Free Floating		After Free Floating	
		(1996.1.3 -1997.12.15)	Excluding Crisis Period	(1997.12.16 -1999.9.30)	Excluding Crisis Period
1	0.328**	0.262**	0.205**	0.301**	0.200**
2	-0.202**	0.066*	0.010	-0.292**	-0.018
3	-0.338**	0.121**	-0.052	-0.441**	-0.082*
4	-0.253**	-0.113**	-0.052	-0.242**	-0.063
5	0.012	-0.092*	0.063*	0.122*	-0.005

Note: Exchange rate change is the first difference of log nominal exchange rate, and *(**) indicates that the statistic is significant at the 5%(1%) level.

16) If the exchange rate changes have some statistically significant sample autocorrelations, the exchange rate changes can be predicted on the basis of their past price action. This is contrary to the weak form of efficiency that investors cannot earn abnormal returns from examining past data. Of course, the implication that the serial autocorrelation goes to the excess return and thus the spot market inefficiency requires that the nominal interest differential plus the risk premium are constant for a while.

17) Traditional serial-correlation tests will not be able to detect the existence of nonlinear dependence.

Ⅳ. Efficiency and Profitability of Technical Analysis

1. Technical Trading Rules

Technical analysis is now widely used in major foreign exchange markets. An investor who rigidly adheres to technical trading rules becomes more influential on the exchange rate determination. Although exchange rates are shown not to have significant autocorelations in the major markets, most studies have also found that technical trading rules would have yielded significant risk-adjusted returns had they been followed in the past. These findings imply that there is some inefficiency inherent in the foreign exchange market, even in the major markets.[18] The profitability of technical trading offers some suggestions in relation to intervention effectiveness and market stability now that the exchange market continues to grow with increasing participants including noise traders.[19]

To distinguish trends from shorter-run fluctuations, technicians employ two types of analysis: charting and mechanical rules.[20] To identify trends through the use of charts, technicians must first find peaks and troughs in the price series, seek out exchange rate patterns and then confirm a reversal of the previous trend. This charting method is very dependent on the interpretation of the technician who is drawing the charts and interpreting the patterns. Mechanical trading rules avoid this subjectivity and are thus more consistent and disciplined. There are two well-known types of mechanical trading rules: filter rules and moving average rules. This paper examines how these two common types of trading rules are formulated and how the returns generated by these rules are measured for market efficiency.

The filter rule advises buying(selling) a currency when it rises(falls) x% above (below) its previous local minimum(maximum), which is expressed as follows:

$$\text{Buy if } S_t \geq (1+x/100)\min\{S_{t-1}, S_{t-2}, \cdots, S_{t-p}\}, \text{ and}$$

18) Some structural features of the foreign exchange market such as asymmetric information, information superiority of market makers and sequential trading, and central bank intervention might explain the market inefficiency.

19) Hung(1991) presents the "chartist channel of intervention" as an alternative channel through which the sterilizing intervention of the central bank influences the trend in exchange rates. For example, by entering an overextended and uncertain market, a surprise round of concerted intervention in a relatively thin market could temporarily disturb flow market equilibrium enough to break the trend in exchange rates. Then, as chartists perceive that the prevailing trend has been broken and that a trend reversal is being formed, they may take on new positions. This will tend to perpetuate the effect of the initial intervention operation.

20) The actual technical analysis is more complex and continues to develop. For example, many technical analysts use support or resistance level, Elliot wave theory and Fibonacci number.

$$\text{Sell If } S_t \leq (1 - x/100) \max\{S_{t-1}, S_{t-2}, \cdots, S_{t-p}\}.$$

The moving average trading rule prescribes a buy(sell) signal when a short moving average(s-days) crosses a longer moving average(l-days) from below (above), which is represented as follows:

$$\text{Buy if } \frac{1}{s}\sum_{i=0}^{s} S_{t-i} \geq \frac{1}{l}\sum_{i=0}^{l} S_{t-i}, \text{ and}$$

$$\text{Sell If } \frac{1}{s}\sum_{i=0}^{s} S_{t-i} \leq \frac{1}{l}\sum_{i=0}^{l} S_{t-i}.$$

2. Test of Efficiency using the Profitability of Technical Analysis

Six moving average rules and six filter rules were tested using the data(see Appendix for computation of returns). [Table 4] shows the annualized percentage returns over each period. The mean annual return to the twelve rules are significantly large over all the periods, which casts doubts on the market efficiency.

It must be noted that most rules get more profitable after free floating than before, when the crisis period is excluded. This suggests that the exchange rate still moves in trends although it is more volatile after the free-floating system is introduced.

[Table 4] Profitability of Technical Trading Rules

(annual return, %)

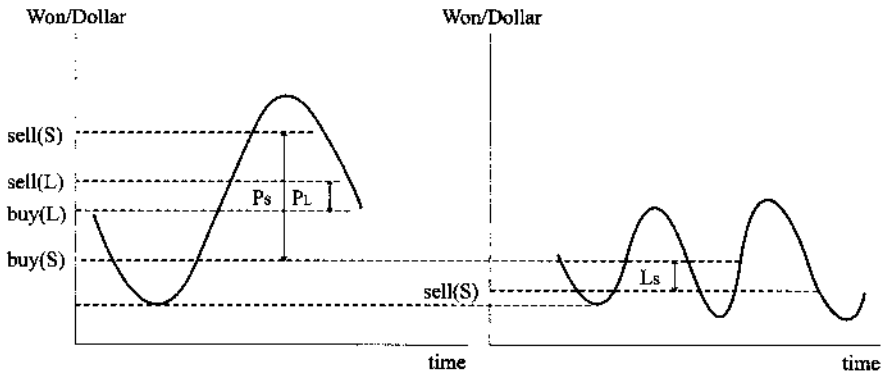
Trading Rule		Whole Period	Before Free Floating (1996.1.3 -1997.12.15)	Before Free Floating Excluding Crisis Period	After Free Floating (1997.12.16 -1999.9.30)	After Free Floating Excluding Crisis Period
Moving Average[1]	1-10	20.2	26.8	7.6	21.9	30.3
	1-20	8.4	25.7	5.9	-3.9	14.1
	1-50	23.8	29.8	8.8	10.6	6.5
	5-10	5.4	23.2	3.6	-8.0	9.1
	5-20	15.9	26.3	6.5	-1.6	15.3
	5-50	24.0	29.3	8.3	10.8	7.8
Filter Rule[2]	0.5	24.5	24.2	3.9	23.5	24.9
	1.0	16.5	16.7	2.0	14.9	16.3
	1.5	18.3	16.6	1.7	18.7	13.5
	2.0	16.3	17.7	1.3	13.3	9.8
	2.5	14.2	17.3	1.1	9.3	5.6
	3.0	7.0	16.2	0.7	-4.6	-3.2

Notes: 1) s-l of moving average indicates the length of the short(s-days) and long(l-days) moving averages.

2) x of filter rule represents a filter size of x percent.

It can be confirmed by examining the excess returns of different filter sizes that the exchange rate still moves in trends even after introduction of the free-floating system. The returns of filter rules increase as the filter size decreases after free floating, which implies that the exchange rate moves in large swings or trends more frequently rather than in a whipsaw fashion as in [Figure 2] below.

[Figure 2] Profitabilities by Market-Swing and Filter Size



The profit(P_S) from trading rule of smaller fiter size(S) is bigger than that(P_L) from rule of larger size(L)

While no signal from trading rule of larger filter size(L), trading rule of samller filter size suffers a loss(L_S).

The profits after the introduction of the free-floating system are generally bigger than those for the major foreign exchange markets,[21] which reflects the market inefficiency as well as the increased post-crisis risk.[22]

For the major markets regarded as relatively efficient, the technical trading rules are profitable, which has been shown to be closely related to central bank intervention.[23]

---

21) The profits, which vary slightly according to the selected rules, objective currencies and sample periods are roughly below 10%. When the same rules are applied to the German mark and Japanese yen for the same period as in this paper, the excess returns are 3~10% as a whole.

22) The higher profitabilities are mainly due to the increased risk premium after the currency crisis. Market inefficiency now should be one of major factors now that the portfolio capital rushes rapidly into Korea and that some of the major markets were inefficient for some time.

23) The central bank is shown to be related with market inefficiency because it sometimes tries to make or reverse a trend on purpose rather than realize profit maximization, and its intervention is one of the critical pieces of information in the market(Lebaron(1996), Szakmary and Mathur(1997), Neely (1997)).

Trading rule profits, excluding the days when the central bank presumably intervenes, are examined in order to investigate whether trading rule profits may also be related with intervention in Korea. The results show that the returns are, as a whole, higher when there is no intervention.[24] Hence, trading rule profits are closely related to intervention in Korea, and further research on this topic will be needed.

Finally, the Sharpe ratios[25] were calculated to examine whether these excess returns are merely compensation for bearing excessive risk. The Sharpe ratios of technical analyses are relatively higher than the 0.01~0.08 values obtained by a simple buy-and-hold strategy in KOSPI. In the end, the higher profitability of trading rules are not compensation for the excessive risk inherent in the trading rules.

[Table 5] Sharpe Ratios of Trading Rules

Trading Rules		Whole Period	Before Free Floating (1996.1.3 -1997.12.15)	Before Free Floating Excluding Crisis Period	After Free Floating (1997.12.16 -1999.9.30)	After Free Floating Excluding Crisis Period
Moving Average	1-10	0.09	0.21	0.14	0.07	0.19
	1-20	0.03	0.19	0.11	-0.10	0.09
	1-50	0.10	0.22	0.15	0.05	0.02
	5-10	0.02	0.16	0.06	-0.04	0.07
	5-20	0.07	0.20	0.12	-0.10	0.10
	5-50	0.11	0.22	0.15	0.05	0.03
Filter Rule	0.5	0.15	0.10	0.10	0.15	0.17
	1.0	0.11	0.08	0.10	0.11	0.12
	1.5	0.13	0.10	0.15	0.12	0.11
	2.0	0.12	0.13	0.16	0.10	0.10
	2.5	0.11	0.12	0.13	0.08	0.07
	3.0	0.06	0.11	0.31	-0.03	-0.05
KOSPI		-0.08	0.01	-0.10	0.08	0.06

24) The exchange rate alternates between upward and downward trends during the sample period and the central bank tries to alleviate or reverse those trends. This situation may form a negative relationship between intervention and exchange rate movement. More detailed discussions have not proceeded because of limited data on intervention.

25) The Sharpe ratio is one measure of risk -- the mean annual return divided by the mean annual standard deviation. Higher Sharpe ratios are desirable because they indicate either higher average excess returns or less volatility. The excess volatility as well as excess returns in the Korean foreign exchange market calls for further research in the future.

V. Summary and Conclusions

Korea's foreign exchange market has been changing in light of increased transaction turnover and volatility since Korea shifted to a free-floating exchange regime and began taking foreign exchange liberalization measures in late 1997. This paper has examined, based on the limited data, the changes in the foreign exchange market after Korea introduced the free-floating exchange system, and evaluated the improvement of market efficiency.

First, the distribution of daily exchange rate changes is leptokurtic and the exchange rate follows a random walk after free floating. Therefore, the high frequency data should now be used with caution in the structural foreign exchange rate models.

Second, the foreign exchange market is still inefficient even after introduction of the free-floating regime now that the autocorrelations of the exchange rate changes are significantly large as a whole and the returns of trading rules are much bigger than in the major foreign exchange markets. That is, volatility is higher after free floating but the exchange rate still moves in trends, which is confirmed by the profitabilities of different size filter rules. The profitability of trading rules is also closely related to central bank intervention.

Despite a lack of consensus surrounding efficiency tests and interpretations, these empirical findings suggest several implications for further research on Korea's foreign exchange market as well as policy measures aimed at improving the foreign exchange system in Korea.

First, the research on Korea's foreign exchange market should be focused on efficiency tests based on the systematic study of risk in Korea, such as mico-structural analysis of asymmetric information and transaction costs. Particulary, the microstructure of Korea's foreign exchange market must be thoroughly examined to pinpoint the structural factors of inefficiency. As the forward market is more activated and risk premium is more deliberately reviewed, the efficiency tests of Korea's foreign exchange market will become more enriched in the near future.

Second, the study of the effectiveness of intervention as well as the establishment of market monitoring is needed now that the trading rules are highly profitable, the participants in offshore NDF markets are using technical analyses, and there are more participants in Korea's foreign exchange market including noise traders. Specifically, the current intervention method through agents must be examined in order to maintain the effectiveness of intervention and raise the price function of the foreign exchange rate.

Finally, the degree of liberalization and opening, both in quantity and quality,

should gradually increase for the development of Korea's foreign exchange market. At the same time, the short-term capital market, financial intermediaries and financial market must also be strengthened in order for the participants in the foreign exchange market to be able to recognize and manage risks in the market.

References

[*In Korean*]

Mo, Soo-Won and Kee, Sung-Rae, "Is the forward exchange market efficient?," *Kukje Kyungje Yongu*, the Korea International Economic Association, Vol. 2 No. 2, 1996, pp. 187-203.

Park, Haeski and Song, Chi-Young, "The predictability of won/dollar exchange rates using information in the offshore NDF market," Korea Institute of Finance, *Journal of Korean Economic Analysis*, Vol. 5 No. 2, 1999, pp. 130-81.

Ha, Hongyun, "An analysis on the efficiency of the foreign exchange market in Korea," Sungkyunkwan University Ph. D. Dissertaion, 1996.

[*In English*]

Corrado, C. J. and Lee, S., "Filter rule tests of the economic significance of serial dependencies in daily stock returns," *Journal of Financial Research*, Vol. 15(4), 1992, pp. 369-87.

Crowder, W., "Foreign exchange market efficiency and common stochastic trends," *Journal of International Money and Finance*, 13, 1994, pp. 551-64.

Dutt, Swana D. and Ghosh, Dipak, "A Note on the Foreign Exchange Market Efficiency Hypothesis," *Journal of Economics and Finance*, Vol. 23(2), Summer 1999, pp. 157-61.

Engel, C., "A note on cointegration and international capital market efficiency," *Journal of International Money and Finance*, 15, 1996, pp. 557-60.

Giddy, Jan H. and Dufey, Gunter, "The Random Behavior of the Flexible Exchange Rate: Implications for Forecasting," *Journal of International Business Studies*, Vol. 6(1), Spring 1975, pp. 1～32.

Hsieh, David A., "The Statistical Properties of Daily Foreign Exchange Rates: 1974～1983," *Journal of International Economics*, Vol. 24(1/2), Feb. 1988, pp. 129-45.

Hsieh, David A., "Testing for Nonlinear Dependence in Daily Foreign Exchange

Rates," *Journal of Business*, 62, no. 3, 1989, pp. 339-68.

Hodrick, Robert J., "Risk, Uncertainty and Exchange rate." *Journal of Monetary Economics*, 23, 1989, pp. 433-59.

Hung, J. H., "Noise trading and the effectiveness of sterilized foreign exchange intervention," *Research Paper, Federal Reserve Bank of New York*, 1991, No. 9111.

Ito, Takatoshi, "Short-Run and Long-Run Expectations of the Yen/Dollar Exchange Rate," *NBER Working Paper*, 1993, No. 4545.

Lebaron, Blake, "Technical Trading Rule Profitability and Central Bank Intervention," *NBER Working Paper*, 1996, No. 5505.

Levich, Richard and Lee Thomas, "The Significance of Technical Trading-Rule Profits in the Foreign Exchange Market: A Bootstrap Approach," *NBER Working Paper*, 1991, No. 3818.

Longworth, David, "Testing the Efficiency of the Canadian-US exchange market under the assumption of no risk premium," *Journal of Finance*, 36(1), March 1981, pp. 43-49.

Meese, Richard and Rogoff, Kenneth, "Empirical Exchange Rate Models of 1970's: Do They Fit Out of Simple?," *Journal of International Economics* 14, February 1983, pp. 3-24.

Neely, C. J., "Technical analysis in the foreign exchange market: A layman's guide," *FRB St. Louis Review*, September/October 1997, pp. 23-38.

Neely, C. J., "Technical analysis and the profitability of U.S. foreign exchange intervention," *FRB St. Louis Review*, July/August 1998, pp. 3-17.

Silber, William L., "Technical Trading: When it works and When it doesn't," *Journal of Derivatives*, Spring 1994, pp. 39-44.

Szakmary, Andrew C. and Ike Mathur, "Central Bank Intervention and Trading Rule Profits in Foreign Exchange Markets," *Journal of International Money and Finance*, August 1997, pp. 513-35.

Rosenberg, M. R., *Currency forecasting, a guide to fundamental and technical models of exchange rate determination*, IRWIN, 1996.

Takagi, S., "On the statistical properties of floating exchange rates: a reassessment of recent experience and literature," *BOJ Monetary and Economic Studies*, Vol. 6(1), 1988, pp. 61-89.

<Appendix> Return to the Technical Trading Rules

To determine whether the technical trading rule is profitable, we assume that a trader holds an amount of money - say ₩1 - in a margin account that collects the Korean interest rate. If the rule directs the trader to buy dollars, the trader borrows ₩1, using the margin as collateral, and converts the borrowed money to a dollar investment at the spot exchange rate. If the trader receives a signal to sell the dollar, he borrows ₩1 worth of dollars - using the ₩1 in his margin account as security - and converts those dollars to a won-denominated bank account.

At first, consider the situation where the rule directs the trader to buy dollars. The won rate of return on the dollar investment is the product of the overnight U.S. interest rate and the rate of appreciation of the dollar against the won. The investor must also pay interest on the won that were borrowed. The gross excess return, R_t, of this strategy over simply holding the margin account is

$$R_t = \frac{S_{t+1}}{S_t}(1+i_t^{\$})/(1+i_t^{₩})$$

where $i_t^{\$}$ is the U.S. overnight interest rate, S_{t+1}/S_t is the appreciation of the dollar against the won overnight, and $i_t^{₩}$ is the Korean overnight interest rate.

The continuously compounded(log) excess return, r_t, is defined as

$$r_t = \ln S_{t+1} - \ln S_t + \ln(1+i_t^{\$}) - \ln(1+i_t^{₩})$$

The return to a dollar short position is the negative of the return to a long position above.[26] Hence, the total excess return, for a trading over the period from time zero to time T is given by:

$$r = \sum_{t=0}^{T} z_t r_t$$

where Z_t is an indicator variable taking the values of +1 for a long position and -1 for a short position.

26) The definition of r_t introduces a very small approximation in the case of a short position.