Foreign Exchange Market Liberalization: The Case of Korea

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Policy Analysis **00-02**

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December 2000

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Preface

The biggest controversy since the occurrence of Asian financial crisis is related with capital liberalization. Until now, capital liberalization was dealt on a global level, as trade liberalization. However, frequent outbreak of crises in connection with capital liberalization has resulted in demands to consider capital liberalization in other aspects. With regards to capital control of developing countries, effective capital liberalization is in active discussion. Most experts suggest that capital liberalization should be accompanied by consistent execution of macroeconomic policy with internal and external economic environment that a country faces, together with healthy, efficient market regulation and supervisory policy. In particular, heavy emphasis was placed on the market players' capability of risk management.

In this respect, the Korean government has actively pursued the liberalization policy on domestic financial markets including foreign exchange market. The government adopted floating exchange rate regime from market average exchange rate (MAR) system just after the crisis. The floating exchange rate regime is expected to eliminate a moral hazard in exchange rates, and allow large adverse shocks to be more easily absorbed than the MAR regime, and thus less likely to provoke currency crises. Furthermore, The liberalization of restrictions on capital markets was accompanied by a relaxation of rules governing the use of foreign exchange. The Foreign Exchange Transactions Law was newly drawn to substitute the old Foreign Exchange Management Law and went into effect in April 1999. In particular, it replaced the positive list system with a negative list system, which allows all capital account transactions except for those expressly forbidden by law. While foreign exchange dealings in the past had to be based on real demand, speculative forward transactions were permitted.

The new system is to be implemented in two stages, in April 1999 and at the end of 2000, in order to allow sufficient time to improve prudential, regulatory and accounting standards before full liberalization. The first stage of the new system has eliminated the one-year limit on commercial loans while liberalizing various short-term capital transactions by corporations and financial institutions. Moreover, foreign exchange dealing was opened to all eligible financial institutions. On the other hands, the second-stage liberalization will focus more on individual participants in the foreign exchange rate market.

This study aims to analyze the effects of the first-stage liberalization on the foreign exchange market in Korea. It is needless to say the importance of the evaluation of the first-stage liberalization, in order to launch the second-stage liberalization measures successfully. We have to understand how much the foreign exchange market has been changed from the implementation of the new system, and implement the liberalization measures, based on the analysis. In this sense, this study will provide valuable information to policy makers at a critical period of time.

The author, Chae-Shick Chung has been a research fellow at the Korea Institute for International Economic Policy (KIEP) since 1998. Sangyoung Joo, former research fellow at the KIEP, is currently a professor of the Department of Business and Economics at Sejong University. Doo Yong Yang, joined the KIEP from 1999, is currently a research fellow at the KIEP.

December 2000,

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Acknowledgements

We would like to thank many reviewers of early drafts of this study. Jongwook Lee, a professor of Seoul Women's University, provides valuable comments. We are also indebted to Yunjong Wang, as a friend and colleague, for extensive comments and suggestions. We thank Yoo-Soo Hong for catching numerous mistakes and encouragement. Excellent research assistance from Young-Min Zang is gratefully acknowledged. This study is in large part of the product of excellent editing staff: Audrey Lee and Kang-Hee Lee.

Non-Technical Summary

The Korean government has liberalized its foreign exchange market in early April 1999. The foreign exchange law has been simplified considerably: it transformed from a positive list system — no transactions allowed, apart from certain explicit exceptions — to a negative list system — all transactions allowed, with a few exceptional cases. As a sequel, the second stage of the liberalization is scheduled for January 1, 2001. Both liberalization actions aim at removing unnecessary regulations for transactions related to foreign exchange, either directly or indirectly, as well as at increasing depth and liquidity of the market.

The purpose of this study can be put simply into the following questions: What are the special features in Korea's won/dollar foreign exchange market distinguished from foreign exchange markets of other major currencies? Does foreign exchange liberalization increase the trading volume and enhance market efficiency of the foreign exchange market? We believe that the answers for these questions may be able to provide useful policy guide for the relevant parties.

Participants in the won/dollar foreign exchange market (interbank market) are composed of the central bank, authorized foreign exchange banks (dealers) and two foreign exchange brokers. As of November 2000, there are 73 foreign exchange banks, consisting of 21 domestic banks, 50 foreign bank branches and two development banks. Any financial institution that wants to engage itself in foreign exchange transactions should get permission from the government. They should meet minimum requirements of capital, manpower, and facilities.

Currently, two commercial foreign exchange brokers are competing in interbank transactions, the Korea Financial Telecommunications & Clearing Institute (KFTC) and Korea Money Broker Corporation (KMBC). The commercial foreign exchange broker system

was introduced to Korea in January 1999. KMBC, a private organization, was allowed to establish a brokerage firm; KFTC, the public foreign exchange broker that enjoyed a monopolistic position in interbank trading, has became a commercial company. These two brokers play an important role in the market. Of all interbank transactions, 96.9% of spot exchange, 63.8% of forward exchange and 93.7% of swap exchange are conducted through both brokers. These numbers are very different from those of other major currencies of which less than 50% of foreign exchange transactions are executed via brokers. Why is brokered interdealer trading a dominant feature in Korea? Simply put, it could be due to the very small size of the foreign exchange market in Korea. Dealers, not wanting to transact directly with other dealers, avoid revealing any trading-related information since the exchange market amounts to only $3 billion or over a day and less than ten banks handle the share of the order flow.

We investigate whether the liberalization measures have induced the market into a more efficient way based on spirits of two very different existing theories: market microstructure theory and market efficiency hypothesis. To test the first one, we use empirical relations between the exchange rate and the trading volume. We see how the market disseminates and reacts to various shocks including private information shocks before and after the liberalization. If the foreign exchange market becomes more efficient after the liberalization, private information shocks should be short-lived or non-existent. We construct the private information shocks as where the exchange rate and the trading volume move at higher than normal revels, respectively. We implement and interpret the shocks within the framework of noisy trading model by Blume, Easley, and O' Hara (1994). The model postulates that information is diffused and incorporated into exchange rate through the trading of informed investors. The uninformed traders infer a new piece of information via the trading volume.

Therefore, the trading process diffuses information as the new piece of information arrives, resulting in a price movement on higher than normal volume. We also take look into how volume shocks and price change shocks affect both the conditional mean and volatility of a variable before and after the liberalization.

We apply the semi-nonparametric (SNP) nonlinear impulse response analysis proposed by Gallant, Rossi and Tauchen (1993) to see how various shocks including the private information shocks affect the variables. The reason we choose the SNP as an empirical tool is that the SNP family of conditional densities is large enough to encompass almost any conditional density, which will minimize the possibility of wrong interpretation of the liberalization measures on account of a specification error. The SNP technique uses Hermite polynomial expansion to directly approximate conditional density. The leading term of the expansion is an ARCH/GARCH. The higher-order terms in the expansion have coefficients which are functions of the conditioning data. In this manner, the polynomial expansion allows for shape deviations from normality and conditional heterogeneity of unknown form. Nonlinear impulse response functions, summarized in Gallant, Rossi and Tauchen (1994), are the extension of the impulse response function of linear VAR to the nonlinear case. In the nonlinear model, the dynamic properties can be elicited by perturbing the vector of conditioning arguments in the conditional density.

Our empirical findings based on nonlinear impulse response functions are as follows. First, large price and volume movements of private information generate persistent responses before and after the liberalization even if the degree of persistence after the liberalization is much smaller than the degree before the liberalization. The results lead us to conclude that the market becomes relatively more efficient after the liberalization, under the framework often going by the name of noisy trading model. That is to say, informed traders may earn much more at the expense of less informed or noisy traders, but the first can enjoy high profits for relatively short duration after the liberalization. Second, the public information shocks do not affect the volatility of the exchange rate in the short run, but the effects do not dampen for a long term in both periods. The same is true for volatility, even though the result is barely statistically significant. Third, the volume shocks or disparate belief shocks are major sources of price deviation from the average exchange rate and persistence in the volatility before and after the liberalization. Therefore, the trading volume itself generates "excessive volatility" in the market.

We also investigate how the foreign exchange market has changed after the liberalization through the relationship between the offshore NDF (Non-Deliverable Forward) exchange rate and the domestic spot exchange rate.

First, we examine the changes in ex-post profit of NDF rates during the sample period. We find the ex-post profit of NDF rate to be very small before the crisis and negative during the crisis period. However, recently the ex-post profit is fluctuating, showing both positive and negative values. It is believed that this comes from the liberalization measure such that domestic banks were allowed to participate in the offshore market since April 1999.

Second, we show the status of market liquidity between the three periods before, during and after the crisis and find that the liberalization has increased the market liquidity. To examine the liquidity condition, the difference between bid-price and ask-price is analyzed, since there is no available data on the trade volume of the NDF transaction. Due to the liberalization, the liquidity in the forward exchange market is expected to increase as more participants enter. The liquidity increased as the bid/ask difference has reduced about four times between period 1 and period 3.

We find that the forward premium puzzle exists in the domestic foreign exchange market. We also find that the influence of crisis still exists in the foreign exchange market. We also obtain empirical results that the offshore NDF exchange rate is not an unbiased indicator. However, the existence of time-varying risk premium explains the bias in the foreign exchange market of Korea. To find the existence of time-varying risk premium, the ARCH-in-mean model is used. ARCH models capture some important aspects of the risk premium in a foreign exchange market. First, the ARCH model is convenient specification for heteroskedasticity, which is an empirical characteristic of exchange rates. Second, most exchange rate changes exhibit leptokurtosis, and the conditional distribution of the Maximum Likelihood procedure of the ARCH model also shows fat-tailed behavior. Lastly, the ARCH-in-mean model is a suitable econometrical model, such that the time-varying risk premium enters into the regression for the conditional mean.

In addition, forward exchange bias clearly appears in the domestic foreign exchange market, indicated by the fact that it did not have a forward premium bias as seen in the main exchange rates in the free-floating exchange rate system. Thus, while most forward exchange rates are known to have a downward bias, an upward bias is observed domestically. This upward bias is thought to be caused by the system collapse following the shock of the financial crisis. Moreover, the upward bias shows that in Korea the interest rate equilibrium condition is satisfied at least in direction. To make an analogy, the government's interest rate stabilization efforts after the crisis greatly helped the exchange rate's downward stabilization. Bias in the domestic foreign exchange market can be explained by checking for existence of a risk premium or peso problem. This means that the domestic foreign exchange market can be understood as the risk premiums of forward exchange buyers and sellers or the expected excess profits (or losses) from expectations of a regime shift.

Based on our empirical findings, we suggest policy implications for exchange and monetary policy. First, the possibility of excessive volatility caused by noise or bandwagon holds a policy implication for the exchange rate system in Korea. Our results show that the degree of excessive volatility in the market grows weaker after the liberalization or adoption of a flexible exchange rate system. It seems to be very contradictory to the general consensus that the exchange rate would be more volatile under a flexible exchange rate system than a fixed one. The clues on the seeming contradiction can be reconciled with the fact that the absolute magnitude of the estimated conditional volatility decreases by more than ten times. As the volatility of the exchange rate decreases, the risk premium become smaller and the incentive for noise traders to participate in foreign exchange transactions shrinks. If the government's policy objective lies in minimizing the exchange rate volatility, one possible candidate for exchange rate system would be multilateral arrangements in the sense of discouraging noisy traders from participating in the market.

Second, indirect intervention of the traditional interest rate policy may not be as much effective as the traditional theory expected. This is due to the risk premium in the determination of exchange rates. The traditional interest rate policy on exchange rate states that increasing domestic interest rates induce more capital inflows and in turn the domestic exchange rates appreciate. However, this would happen only if interest rates and foreign exchange risk premiums were orthogonal. In other words, the exchange rate depreciates rather than appreciates in the case that the increasing interest rate influences the risk premium as a sign of weak economic conditions. According to empirical analysis, the changes of exchange rates depend on the interest rate differential as well as the risk premium. Since the forward rate and realized expected spot rate are correlated positively, as the interest rate differential increases, capital outflows occur and the domestic currency depreciates. As the time-varying risk premium is deemed as an important factor in the foreign exchange market, it is better to understand the effect of risk components in determination of the exchange markets.

Development of the domestic bond market is also another important economic objective for the Korean economy. An efficient and active bond market provides not only effective benchmark rates in the foreign exchange transactions, but also alternative financial assets to diversify the risk. This results in a deeper and more efficient foreign exchange market. In conclusion, the development of foreign exchange market requires a more efficient domestic financial market in general.

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I. Introduction

Many East Asian countries which suffered from the economic crises in 1997, particularly Thailand, Malaysia, Indonesia and Korea, have since sought various ways to increase the resilience of their economy to external shocks. A general direction for them, except Malaysia, was to adopt a fully flexible exchange rate arrangement and further liberalize their capital market. An intermediate regime between the two polar solutions, i.e. hard fixed and floating exchange rate regimes, was not easy to keep due to the deep economic integration of developing countries. Also, capital market liberalization aimed to enhance benefits of financial flows. Therefore, crisis countries came to accept the expansion of capital flows as an inevitable and irreversible result of globalization.

To adapt to the changing global financial environment, the Korean government has taken action to liberalize foreign exchange transactions from early April 1999. The 「Foreign Transaction Law」 was newly enacted to replace the 「Foreign Exchange Management Law」. The new law is simplified considerably: it has been transformed from a positive list system—no transactions allowed, apart from certain explicit exceptions —to a negative list system—all transactions allowed, with a few exceptional cases. Also, the principle of "real demand requirement" for forward contracts was scrapped, increasing speculative transactions and thereby foreign currency trading volume.

As of January 1, 2001, most of restrictions on foreign exchange transaction are to be abolished. The government will maintain a number of measures to strengthen prudential regulations and closely monitor capital flows. First, the government will hold up regulations on local fund borrowing by non-residents that can potentially be used to attack the local currency. They cover direct local currency borrowing or indirect borrowing through the issuance of bonds denominated in local currency, or other types of derivative transactions. Second, the government will regulate overseas short-term borrowing by domestic firms if they do not meet prudential requirements such as appropriate capital ratio. The regulation aims at discouraging excessive short-term external financing from abroad, which was a cause of the Korean crisis, and at making corporate restructuring more effective. Third, the government will continue to give qualified consent to resident firms' overseas assets valued at over US$50,000; however, they are required to report the status of their offshore assets to the government and repatriate the assets upon failure to meet certain conditions.[1]

The purpose of this study lies in the evaluation of the effects of the first-stage liberalization on the won/dollar foreign exchange market in Korea. The contribution of this study, therefore, is originality. No previous research has investigated analytically the effects of the foreign exchange liberalization in Korea, as far as we recognize. We delve into the question of how the liberalization measures have changed the market and, if so, whether the market has evolved in a desirable way. The term "desirability" will be judged on the basis of various efficiency concepts in either a single representative rational expectation framework or a heterogeneous agents model as postulated by market microstructure study.

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[1] More formally, it is called the "Obligation of Recovery of Claims." The term is specified in chapter 7 of Foreign Exchange Transact Act: "The Minister of Finance and Economy may, pursuant to the Presidential Decree, require residents holding claims against nonresidents to collect such claims and to recover them to the Republic of Korea, if it is deemed necessary for the stabilization of the foreign exchange market, etc. to do so".

Generally speaking, our work tends to be very data-based and not guided by rigorous equilibrium models of market behavior. That is, the models are more statistical than economic in character, and typically neither the optimization problem facing agents nor the information structure is fully specified.

First, we examine the market efficiency based on microstructure study where the informed traders or traders with superior information can make positive gains at the expense of less informed market participants. Therefore, the definition of efficiency is different from the analysis in the following section wherein market participants cannot earn economic risk-adjusted profits on the basis of available information. Using empirical relations between the exchange rate and the trading volume, we will see how the market disseminates and reacts to private information and public information shocks.

We design the private information shock as a situation in which both the exchange rate and the volume of trade deviate substantially from their own normal levels. The economic rationale for this setting has its roots in noisy rational expectation models (Blume, Easley and O' Hara, 1994) which postulate that volume allows traders to sort out the effects of the quality of information from the direction of information effects embedded in prices. If the foreign exchange market becomes more efficient after the liberalization, private information shocks should be short-lived or non-existent. Our work is motivated by recent investigations which suggest that more can be learned about the market by studying prices in conjunction with volume, instead of prices alone, of the stock market.

To some, it could seem absurd to use private information shocks in any foreign exchange market because participants in the foreign exchange market utilize the same public information set. That is, foreign exchange markets differ greatly from equity markets where, for example, individual analysts have private information on corporations. However, numerous literatures argue that private information exists in the foreign exchange market. Ito, Lyons, and Melvin(1997) contend that foreign exchange dealers have price-relevant private information. Lyons (1997) also claims that private information is prevalent in the foreign exchange market since customer order flows are not part of public information.

Second, efficiency of the domestic foreign exchange market has been examined through the relationship between the offshore NDF (Non-Deliverable Forward) exchange rate to the domestic spot exchange rate. In order to analyze the effects of the foreign exchange market liberalization, we investigate the market efficiency in different periods, especially before and after the implementation of liberalization measures.

From the perspective of foreign exchange market efficiency, the question arises whether the offshore NDF exchange rate is an unbiased, and therefore accurate, predictor of the domestic spot exchange. While most economists agree that the forward exchange is not an accurate predictor of the future spot exchange rate, there is no consensus on whether this indicates market inefficiency or not. A market is inefficient when biases continuously occur in the forward exchange and the future spot exchange, even though market participants are risk-neutral with rational expectations. Bias in the forward exchange can be explained by either of the two explanations. The first explanation is that forward exchange bias is continuously created by the risk premium, arising from the fact that market participants are not risk-neutral. The second is what is known as the "peso problem"[2]: expectations of a regime shift, such as adoption of a new exchange rate system or government intervention in the foreign exchange market, are

[2] The first written discussion of the "peso problem" appears in Rogoff (1980).

reflected in the forward exchange. The study examines how the theory of rational expectations can explain the forward exchange bias, if it exists, in the domestic foreign exchange market.

By looking at the market liquidity in three periods, we find that the liberalization has increased the market liquidity. As the liberalization extended, the liquidity in the forward exchange market is assumed to increase as more participants enter the market. To examine the liquidity condition, we assess the difference between bid price and ask price, since there is no available data on the trade volume of the NDF transaction. We also examine whether the "forward premium puzzle", which arises when interest rate equilibrium conditions do not hold between the offshore NDF exchange rate and the spot rate, exists in the domestic foreign exchange market. We investigate whether such bias can be explained by the existence of the peso problem.

The study is structured as follows. In chapter II, we review the foreign exchange market in Korea. We present the structure and participants of the market, the history of the exchange rate regime and the recent liberalization measures. Chapter III evaluates the liberalization of foreign exchange markets using exchange rate and trading volume. We begin with an estimation and interpretation of a semi-non-parametric (SNP) model of the conditional joint density of exchange rate and volume. The conditional density itself is the fundamental statistical object of interest, as it embodies all of the information about the probabilistic structure of the data. Then, we proceed ultimately to see what has changed in the market after the liberalization. We also discuss relevant empirical evidence whether liberalization induces the market to be efficient. Chapter IV contains the theory explaining the bias between forward and spot exchange. We use unit root and co-integration analyses of the domestic spot exchange and the offshore NDF forward exchange for an empirical test of forward exchange. In the final chapter, we conclude with a brief summary and policy suggestions.

II. Foreign Exchange Market in Korea

1. Structure and Participants

The foreign exchange market in Korea is composed of a customer market, where foreign exchange banks transact with firms or financial institutions, and an interbank market, where certified foreign exchange banks[1] deal among themselves and the exchange rate is determined. Major players in the interbank foreign exchange market are the central bank, authorized foreign exchange banks (dealers) and two foreign exchange brokers, the Korea Financial Telecommunications & Clearing Institute (KFTC) and Korea Money Broker Corporation (KMBC).

In the customer market, major players are the firms engaging in export and import; they participate for the purposes of hedging foreign currency exposure, acquiring trade-related credit facilities and simply exchanging foreign currencies. The authorized foreign exchange banks (dealers) make transactions to adjust their positions in the interbank market. As seen in Table II-1, of all interbank transactions, 96.9% of spot exchange, 63.8% of forward exchange and 93.7% of swap exchange (as of 1999) are conducted through either KFTC or KMBC. Especially for spot transaction, brokered interdealer trading is a dominant phenomenon that is in sharp contrast to foreign exchange markets of major currencies where half of spot trading volume is executed via

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[1] Ministry of Finance and Economy (MOFE) requires all financial institutions to get permission for foreign exchange transaction with such requirements as capital, manpower and facilities. Such financial institutions are called "foreign exchange business institutions" and, among them, banks are exclusively referred to as "foreign exchange banks." As of November 2000, there are 73 foreign exchange banks, consisting of 21 domestic banks, 50 foreign bank branches and two development banks.

interdealer trading. Interdealer trading dominance might be due to the very small size of foreign exchange market in Korea. Dealers, not wanting to transact directly with other dealers, avoid revealing any trading-related information since the won/dollar exchange market amounts to only $3 billion or over a day and less than ten banks handle the share of the order flow. Therefore, dealers are likely to prefer not to reveal his/her identity before the trade is executed in order to get a best price via brokers. Since most of the interbank transactions are conducted through two brokers, it has the advantage of making it easier for the government to closely monitor and supervise the foreign exchange market. However, it also has a disadvantage of interrupting market efficiency by regulating market participants too strictly.

<Table II-1> Interbank Transactions in 1999

(unit: million, US$)

	Through FTC	Over-the-counter (OTC)
Spot	412,674.40 (96.87%)	13,312.08 (3.13%)
Forward	1,054.10 (63.83%)	597.35 (36.17%)
Swap	174,654.80 (93.65%)	11,838.63 (6.35%)

Source: KFTC

There are three types of foreign exchange instruments in the market. Until recently, only spot transaction has been used extensively by foreign exchange market participants. As shown in Tables II-1 and II-2, swap transactions have increased significantly from 1999, while forward transactions have decreased to the point of showing 0% in 1999. The increase of swap transactions in the foreign exchange market should be considered as a major change after floating exchange rate regime was adopted.

<Table II-2> Types of Foreign Exchange Transactions

Classification	Spot	Forward	Swap	Total
Korea	49.8%	0.0%	50.2%	100%
World Average	39.0%	7.9%	53.1%	100%

Source: Bank of Korea (1999), BIS (1998)

<Table II-3> Trend of Foreign Exchange Transactions

(unit: million, US$)

	1994	1995	1996	1997	1998	Sep. 1999
Spot	1,133	1,833	1,659	1,825	1,002	1,698
Forward	936	149	24	96	6	0
Swap	-	-	-	8	88	1,713
Total	2,069	1,982	1,683	1,929	1,096	3,412

Source: Bank of Korea

2. Exchange Rate Regime and Liberalization Measures in Korea[2]

After 16 years of single currency peg (SCP) system against the U.S. dollar, the multiple currency basket peg (MCBP) system was introduced to Korea in March 1980. Under the MCBP system, exchange rate was determined by a formula that reflected changes in the special drawing rights (SDR) basket, the independent basket and the “policy factor.” While the composition of the SDR basket was disclosed by the IMF every five years, the composition of the independent basket was never disclosed. It is generally believed that the independent basket consisted of the currencies of Korea’s

[2] See Park, Chung and Wang (1999) for more detailed description.

major trading partners, namely the U.S., Japan, Germany and Canada. Moreover, even though the "policy factor" was considered to be the most influential factor in determining the exchange rate regime, much less information on policy factor was revealed. It is assumed that this factor was utilized to provide the inputs necessary for the exchange rate to reflect the current situation.

In the late 1980s, Korea recorded huge trade surpluses against the U.S. and the Korean government was accused of manipulating the "policy factor" variable to its advantage. The Korean government, persuaded by the U.S., introduced current account convertibility of the Korean won through the acceptance of the obligations stipulated in Article VIII of the IMF. The managed floating exchange rate regime, which was put into effect in 1990, was called the market average exchange rate (MAR) system. Since the won-dollar exchange rate under this system was in principle determined by the market forces, the interbank foreign exchange market developed rapidly. In order to promote the new exchange rate system, the Korean government relaxed the regulations on foreign exchange concentration.

Under this system, the basic won-dollar rate was the market average rate of the previous day, determined by the weighted average of market exchange rates, whose weights were volumes of each transaction. The basic rate was announced in the morning of each trading day by the Fund Trading Center (FTC) of the Korea Financial Telecommunication and Clearing Institute. The exchange rates of the won with respect to other currencies were determined by the cross rates, as done in the past. They were calculated on the basis of rates quoted in both the Tokyo and New York foreign exchange markets and used as reference rates for the commercial banks without restrictions on the spreads.

Under the MAR system, the intraday fluctuation of the won-dollar spot rate was restricted within a narrow band. The “window guidance” of the Bank of Korea (BOK) limited the banks from quoting rates too close to the upper or lower limits of the band. In addition, unlike developed foreign exchange markets, the Seoul Foreign Exchange Market did not allow the entry of any foreign exchange brokerage firms. In fact, the FTC took most of the share of the interbank transactions with only 3.2 percent being carried out by the over-the-counter (OTC) market in 1995. Thus, the BOK was able to closely monitor the foreign exchange market. This supervision may have helped maintain the market’s stability but it may also have discouraged active price quotations by the banks as market makers.

During the period of the MAR system, extensive measures of liberalization have been conducted. In January 1992, foreigners were allowed to purchase Korean stocks up to three percent of the outstanding shares of each company per individual, but no more than ten percent of a company in total. The Korean government in June 1993 put forth a blueprint for the liberalization and opening of the financial sector, aiming at substantial progress in the financial market deregulation. The plan envisaged further easing of requirements for foreign exchange transactions, widening the daily won-dollar trading margins, expanding limits on foreign investments in the stock market and permitting long-term commercial loans.

Further capital account liberalization became inevitable when Korea joined the OECD in 1996. However, the Korean government maintained many reservations to the code of liberalization of capital movements and current invisible operations. According to the membership negotiations, Korea was reluctant to liberalize its capital account out of concern about a dramatic increase in foreign capital inflows due to the interest rate differentials between home and abroad. The government had thus planned to delay capital account liberalization until the interest rates converged significantly.

Thailand’s sudden decision to float the Thai baht on July 2, 1997 also caused the Korean won to depreciate rapidly. Following futile attempts of currency defense, the Korean government widened its won trading band from 2.25 percent to ten percent on November 19, and finally abolished its band to allow the won to float on December 16.

With the free floating exchange rate system in place, the Korean government also accelerated its ongoing capital account liberalization plan. Under the IMF program, the Korean government agreed to undertake bold liberalization measures. The capital markets, including the short-term money markets, and the real estate market which was once off-limits and considered non-negotiable were all completely opened to foreigners in the 6th Letter of Intent dated May 2, 1998 to the IMF.

Most of the important measures of liberalization have been adopted during the free floating exchange rate regime period under the IMF program. In December 1997, the government raised the ceiling on the overall foreign ownership of stocks to 50 percent in 1997 from the previous ceiling of 26 percent. The individual ceiling was raised from seven percent to 50 percent. These ceilings were lifted completely on May 25, 1998. All regulations on foreign purchases of debt securities were eliminated in December 1997. As of December 1997, all domestic enterprises, regardless of size, were allowed to borrow without limit from overseas, as long as the maturity did not exceed one year. All the short-term money market instruments, such as commercial papers and trade bills, were also fully liberalized on May 25, 1998.

The liberalization of restrictions on capital movements was accompanied by a relaxation of rules governing the use of foreign exchange. The Foreign Exchange

Transactions Law was newly drawn to substitute the past Foreign Exchange Management Law and went into effect in April 1999. In particular, it replaced the positive list system with a negative list system, which allows all capital account transactions except for those expressly forbidden by law. While foreign exchange dealings in the past had to be based on bona fide real demand, speculative forward transactions were permitted.

The new system is to be implemented in two stages, in April 1999 and at the end of 2000, in order to allow sufficient time to improve prudential, regulatory and accounting standards before full liberalization. The first stage of the new system eliminated the one-year limit on commercial loans while liberalizing various short-term capital transactions by corporations and financial institutions (see Table II-4). Moreover, foreign exchange dealing was opened to all eligible financial institutions.

<Table II-4> The First Stage of Foreign Exchange Liberalization (April 1999)

Area	Liberalization Measures
Current Account Transactions	- Abolition - Abolition of restrictions on companies in current account transactions with foreigners
Transition from a Positive List System to a Negative List system	- Abolition of restrictions on the use of loans borrowed by the foreign subsidiary of a domestic company - Companies are allowed to borrow from overseas, provided maturity is less than one year, and to issue overseas securities - Deposit by non-residents with maturity of more than one year and their investment in trust funds are allowed - Removal of restrictions on foreign direct investment abroad by domestic companies and financial institutions (including the unrestricted establishment of overseas branches)

	- Investment by companies and financial institutions in foreign real estate is permitted - Investment in overseas securities by domestic institutional investors is allowed - Domestic issuance of securities by foreigners is allowed - Abolition of the real demand principle
Foreign Exchange Dealing	- All types of domestic or foreign financial institutions can deal in foreign currencies - Establishment of money exchange booths is allowed

Source: Ministry of Finance and Economy, Korea

With the first stage of foreign exchange liberalization being introduced, another two important institutional changes are worthy of note. First, the commercial foreign exchange broker system was introduced in January 1999; private organizations were allowed to establish brokerage firms. Also, the KFTC, the public foreign exchange broker that enjoyed a monopolistic position in the interbank trading, became a commercial company. Currently, two commercial foreign exchange brokers are competing in interbank transactions. However, as trading volumes are growing in the Seoul Foreign Exchange Market, more brokers are expected to enter the brokerage market. Second, currency futures and options were introduced in the Pusan Futures Market in April 1999 so that companies and financial institutions exposed to foreign exchange risks could effectively use these hedging instruments.

3. Some Stylized Facts of Intraday Volatilities

Before we formally investigate the foreign liberalization effects on the market, it is quite instructive to see changes in volatility patterns of the won/dollar exchange rates before and after the liberalization. The volatility of asset returns is of great interest to the financial economists as well as financial policy makers. As a preliminary investigation, we focus on whether lifting restrictions related to foreign exchange raised the exchange rate volatilities. Another issue is the persistency of exchange rate volatilities. Of interest is whether the liberalization increased volatility. In fact, however, the level of volatility itself is not related to the efficiency of foreign exchange markets. Rather, the persistency issue is more important because it is related to how quickly returns and volatilities reflect news-arrivals or information-flows in the market. We will examine these issues using intraday data on exchange rate returns.

3.1 Characteristics of Intraday Volatilities

Our six-month data set constitutes ten-minute returns for the won/dollar spot exchange rate from January 1 through June 30, 1999.[3] The starting date is dictated by the availability. The ten-minute returns were constructed from the won/dollar exchange rate quotes. Each quote contains a bid and ask price. We use the logarithmic ask price to construct intraday 10-minute returns. The i'th return within day t, $R_{t,i}$, is the change in log prices during the corresponding period; i.e., $R_{t,i}$, i=1,2,...,n, t=1,2,...,T. In our sample, T is 118 and *n* depends on days.

One common approach used in the evaluation of daily frequency volatility estimates relies on direct comparison with the corresponding realized squared returns or

[3] In precise, our intraday returns are "approximate" ten-minute returns since some prices are measured not exactly for the ten-minute intervals (for example, 8 to 12 minute intervals).

absolute returns.

$$R_t^2 = (\ln P_t - \ln P_{t-1})^2, \text{ or } \quad |R_t| = |\ln P_t - \ln P_{t-1}|.$$

However, realized squared or absolute daily returns are imprecise gauges of the underlying volatility. For example, the price may fluctuate rather wildly, but nonetheless ends up close to the opening price, thus falsely signaling a low volatility state.

Rather than squared or absolute daily returns, return volatility has also been addressed by the autoregressive conditional heteroskedasticity (ARCH) or the generalized autoregressive conditional heteroskedasticity (GARCH). However, daily volatility measures generated by ARCH-GARCH models have disadvantages in that they are not observed on a day-to-day basis. That is, daily volatilities based on the ARCH-GARCH are ones that have not been realized.

Hence we use different measures for daily volatilities using intraday returns. The first measure is defined as the standard deviation of intra-day 10-minute returns during day t, i.e, $V_t^1 = \sigma(R_{t,i})$. Returns will be driven by underlying news-arrivals or information-flows. Thus the above average level of news-arrivals or information-flows will make returns more volatile during one day. In this sense, the standard deviation of intraday returns will measure how volatile high frequency returns during one day.

The second measure of volatility is defined as the difference between maximum and minimum log values of exchange rates each day, i.e., $V_t^2 = \ln P_{t,max} - \ln P_{t,min}$, where

$P_{t,max}$ and $P_{t,min}$ are maximum and minimum prices during day t. This measure, representing the maximum variability of intraday prices, may overcome the disadvantages of simple squared or absolute daily returns of closing prices of consecutive days.[4]

<Table II-5> Summary Statistics of V^1 and V^2 : January 4, 1999 – June 30, 1999

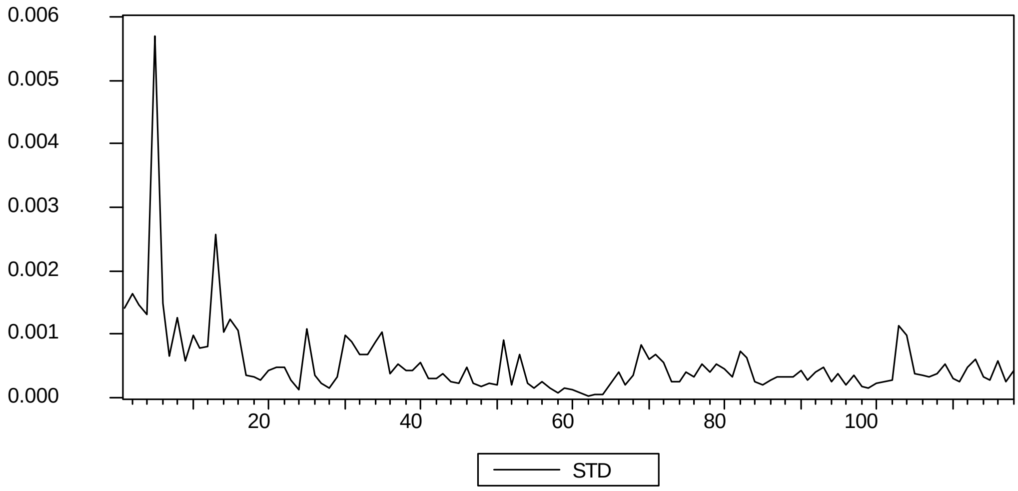
	Mean	Median	Max	Min	Std.dev	Skewness	Kurtosis
V^1	5.44×10^{-4}	3.68×10^{-4}	5.69×10^{-3}	3.75×10^{-5}	6.18×10^{-4}	5.40	42.78
V^2	5.63×10^{-3}	4.82×10^{-3}	2.65×10^{-2}	2.00×10^{-4}	3.86×10^{-3}	1.98	9.68

Note: V^1 is defined as the standard deviation of intra-day 10-minute returns during a day. V^2 is defined as the difference between maximum and minimum log values of exchange rates each day

According to Table II-5, two distributions of volatilities are both skewed and fat-tailed, but the degree of skewness and kurtosis of V^2 is milder than those of V^1. The correlation coefficient between V^1 and V^2 is 0.82, which is higher than expected, indicating that those two measures of intraday volatility show similarities, despite different definitions.

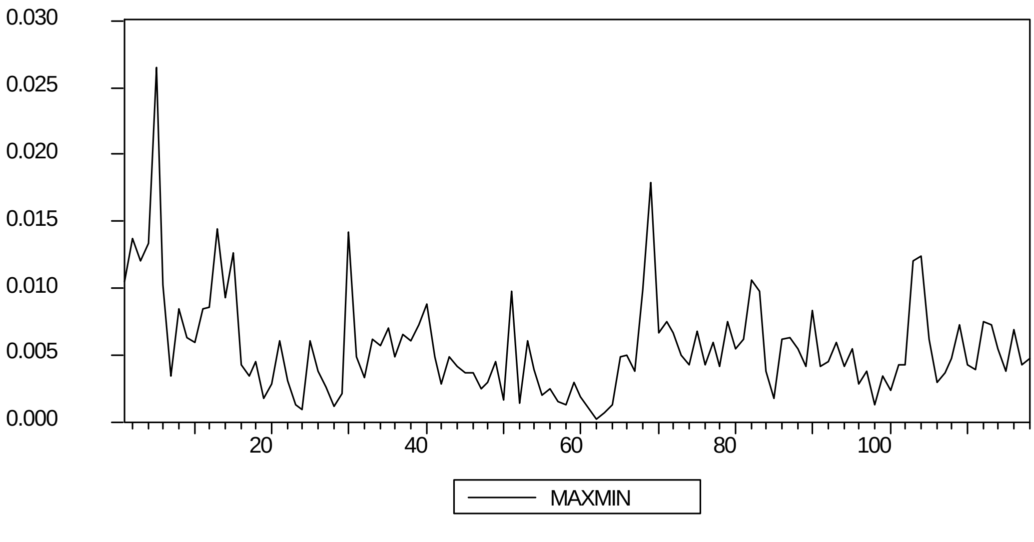
[4] A rather richer measure for the latent volatility might instead be based on the intraday absolute returns, i.e., 1n $|R_{t,i}|$. This measure can be referred to as the cumulative absolute returns. In our sample, however, since intraday returns are measured for approximate ten-minute intervals, the number of returns in a day is not exactly the same across days. So the simple sum of intraday absolute returns may cause measurement problems in our sample.

<Figure II-1> Trend of V^1 : January 4, 1999 – June 30, 1999



Note: The notation STD stands for V^1 and the 57^{th} observation corresponds to April 1, 1999.

<Figure II-2> Trend of V^2: January 4, 1999 – June 30, 1999



Note: The notation MAXMIN stands for V^2 and the 57^{th} observation corresponds to April 1, 1999.

Figures II-1 and II-2 show trends of two intraday volatilities during January 1999 through June 1999. One may expect a volatility increase after the liberalization of April 1, 1999; glancing at the trend, however, volatilities seem not to increase after the liberalization.

<Table II-6> Unit Root Test

	V^1	V^2	1% critical value
ADF-statistic	-8.586	-5.802	-3.489

Note: The intercept and four lags are included for the ADF-tests.

Also, the two series turn out not to contain unit roots, which signifies that those two volatility measures are stationary. Table II-6 shows ADF-test statistics of unit root. This result, along with the volatility patterns shown in Figures II-1 and II-2, indicates that intraday volatility series are stationary around the unchanged mean level for the pre- and post- liberalization periods.

<Table II-7> Level Changes in Volatilities

	Mean		Median	
	Pre-Liberalization	Post-Liberalization	pre-liberalization	post-liberalization
V^1	7.42×10^{-4}	3.65×10^{-4}	4.79×10^{-4}	3.31×10^{-4}
V^2	6.12×10^{-4}	5.19×10^{-4}	4.90×10^{-3}	4.63×10^{-3}

We have examined whether the liberalization raised the volatility level of exchange rates. According to Table II-7, volatility levels, whether measured as mean or median, have been reduced after the liberalization. This indicates the liberalization had not affected the volatility of exchange rates.

This result of unaffected volatility can be confirmed with regression analysis. We will see if the liberalization dummy variable has additional explanatory power for the intraday volatilities.

<Table II-8> Autoregressive Models of Volatilities

Dep.Var	Constant	AR(1)	AR(2)	AR(3)	Dummy	adj.R^2	D-W
V^1	0.000 (0.002)	0.264 (0.000)	0.097 (0.196)	0.238 (0.018)	-	0.20	2.00
V^1	0.000 (0.004)	0.248 (0.000)	0.081 (0.266)	0.217 (0.021)	-0.000 (0.128)	0.20	1.99
V^2	0.002 (0.000)	0.475 (0.000)	-	-	-	0.22	2.08
V^2	0.003 (0.000)	0.469 (0.000)	-	-	-0.000 (0.515)	0.21	2.07

Note: Values in parentheses are p-values, which are based on standard errors of Newey-West(1987). The D-W means Durbin-Watson statistics.

Since we cannot find any other proper explanatory variables, we apply autoregressive models to two types of volatilities. The AR(3) and AR(1) models come out as suitable for V^1 and V^2, respectively. However, the liberalization dummy variable lacks statistical significance, even showing negative estimates. Including the liberalization dummy variable did not improve the autoregressive model's fit at all. This result confirms that there is no significant change in the volatility of the won/dollar exchange rates occurred after the liberalization.

3.2 Changes in the Autocorrelations Structure

Next, we examine whether autocorrelation structure is changed after the liberalization. Let us first examine the autocorrelation in returns series. In the following argument, daily returns are defined as logarithmic differences of daily closing prices. Joo (1996) and Chung and Joo (1999) point out that strong autocorrelation exists, especially up to the second order, in daily returns on the exchange rate since March 1990 when the Market Average System was introduced. In our sample of the first half of 1999, this result is still valid.

<Table II-9> Autocorrelations in Won/Dollar Exchange Rate Returns

	Autocorrelation			Partial Autocorrelation		
	Whole	Pre-Lib.	Post-Lib.	Whole	Pre-Lib.	Post-Lib.
ρ_1	0.183	0.165	0.149	0.183	0.165	0.149
ρ_2	-0.028	-0.041	-0.109	-0.064	-0.070	-0.134

Note: Notations ρ_1 and ρ_2 are the first and second order (partial) autocorrelation coefficients, respectively.

As Joo (1996) and Chung and Joo (1999) report around 0.1 to 0.2 of the first order autocorrelation for the sample of early 1990 through mid-1998, strong first order autocorrelation still exists for the first half of 1999 sample. The liberalization of April 1, 1999 seems not to have changed the autocorrelation structure in returns series prevalent ever since the early 1990s. The second order autocorrelation looks mitigated, but not for the post-liberalization sample.

Strong autocorrelations are found not only in returns but also in volatilities. Joo and Hahn (1999) found that exchange rate volatility possesses a long-memory characteristic for the sample period encompassing July 1991 to August 1998. They used both squared and absolute returns as daily volatilities. Both commonly used volatilities turn out to have fractionally-integrated process. The long-memory characteristic may be evidence against the foreign exchange market efficiency.

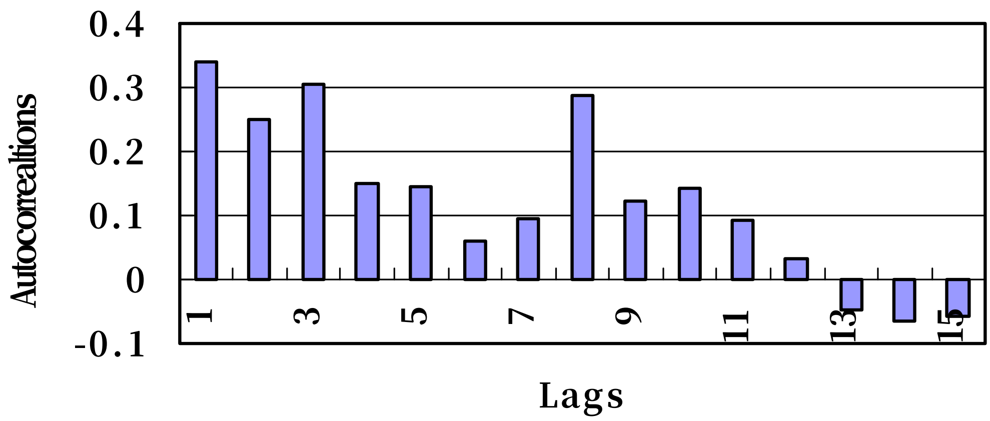
According to Joo and Hahn (1999), this long-memory characteristic seems to be related to several factors. A thin market due to the locality of the won and various restrictions on trading may hinder efficient processing of newly arrived information to the market. The underdevelopment of the futures market may also contribute to the delayed processing of information.

For the different samples and different measures of volatility we have used so far, let us now examine the autocorrelation structure in intraday volatilities. Due to the shortage of sample, we describe autocorrelation functions for the pre- and post-liberalization sample.

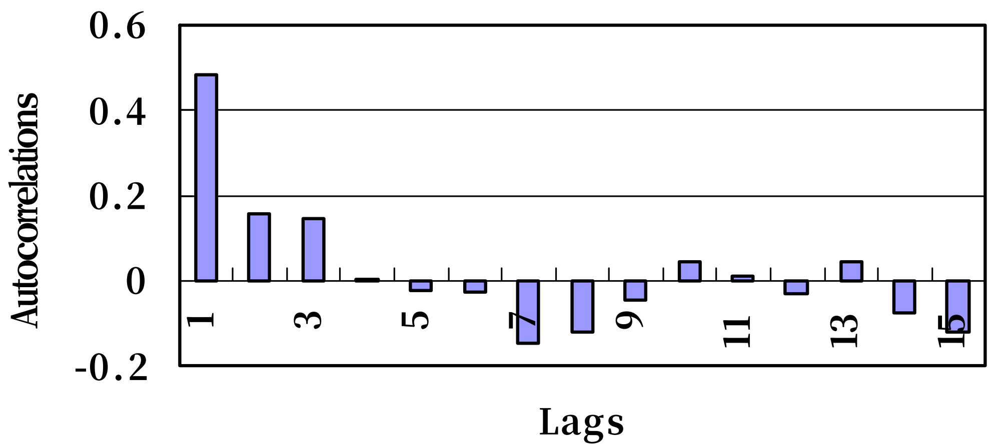
Figures II-3 through II-6 plot autocorrelation functions of two measures of intraday volatilities. As can be seen in these figures, the autocorrelation structure seems to have been changed. Before April 1, 1999, autocorrelation did not die out for almost ten days for both volatility measures. After April 1, however, autocorrelation died out quickly, living only for three to four days. Strong and persistent autocorrelation in volatilities means that shocks to the foreign exchange market do not die out quickly. In this sense, the speed of adjustment to shocks has been increased.

Changes in autocorrelation structure after the liberalization seem to be related to the development of futures market. As of April 1, 1999, the so-called “real demand principle” was lifted, facilitating foreign exchange transactions from speculative motive. The real demand principle had been an important factor restricting enough liquidity in the won/dollar market of Korea.

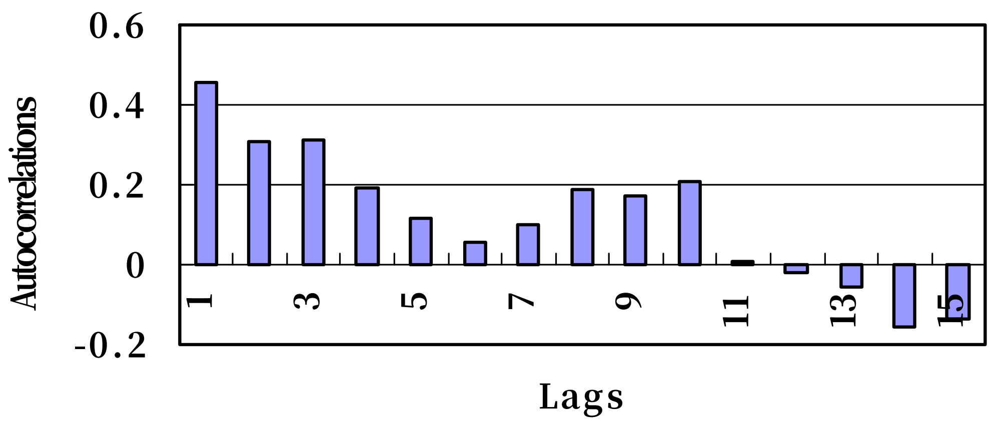
<Figure II-3> Autocorrelations of V^1 before the Liberalization



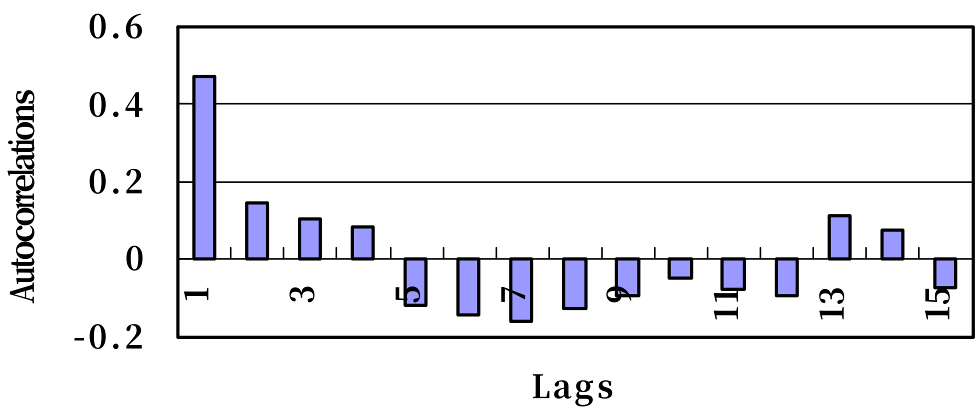
<Figure II-4> Autocorrelations of V^2 after the Liberalization



<Figure II-5> Autocorrelations of V^2 before the Liberalization



<Figure II-6> Autocorrelations of V^2 after the Liberalization



Actually, futures trading volume increased dramatically after the liberalization. In 1998, the average futures trading volume during one day was only \$90 million. The number had increased to \$220 million for the first quarter of 1999. In the second quarter of 1999 when the liberalization measures have become effective, the daily average futures trading volume increased \$530 million, more than doubled comparing to the previous quarter. The upward trend accelerated after the liberalization; now the trading futures trading volume exceeds \$2 billion a day.

Liquid futures markets can enhance market efficiency through appropriate and instantaneous formation of price expectations in response to arrivals of new information to the market. Whether good or bad, news-arrivals cause price changes, thus volatility. If such news is efficiently processed among participants in the market, newly increased volatility will not persist for a long time. Active futures market usually facilitates efficient information processing. The finding that autocorrelations in volatility died out relatively quickly than before the liberalization can be interpreted as an evidence favoring the improvement of market efficiency.

However, due to the fact that strong first order autocorrelation still exists in return series and autocorrelations in volatility have been mitigated only in a relative sense, we cannot conclude that there is a dramatic change in market efficiency after the liberalization.

Before dealing with market efficiency issue more rigorously, this section focuses only on time series properties of exchange rates, especially of intraday volatility patterns. In general, removal of various restrictions on transactions generates market liquidity and hence efficient information processing. Expectations in liquid and thick markets are that extra profit opportunities are limited and private information will not play an important role. In the next two chapters, we will discuss this issue.

III. Trading Volume and Exchange Rate Dynamics

The purpose of this chapter is to investigate whether the foreign exchange market has gained efficiency after the liberalization more formally. Based on a noisy rational expectation model as postulated by Blume, Easley and O'Hara (1994) where traders learn from observing volume and therefore the volume itself affects the adjustment of prices to information, we empirically test whether private information becomes short-lived or non-existent after the liberalization. Therefore, we judge the enhancement of efficiency through whether or not the shocks disseminate in the market more rapidly. Also, we see how the market reacts to public information shocks (only price change) and trading volume shocks before and after the liberalization. We first estimate empirical relations between the exchange rate and the trading volume and secondly investigate how the market reacts to various above-mentioned shocks.

We begin with the estimation and interpretation of a semi-non-parametric (SNP) model of the conditional joint density of the exchange rate and volume. Based on the estimation results of SNP, we see how the market has changed after the liberalization. To this end, we undertake a nonlinear impulse response analysis by utilizing the method developed by Gallant, Rossi, and Tauchen (1993). With the analysis, we compare the responses of the reactions of conditional moments of the exchange rate change and the trading volumes to various shocks without relying on specific parameterization of mean and variance equations.

The main reason of choosing SNP as the fundamental statistical objective of interest, in a word, is to avoid the possibility of wrong interpretation of the liberalization measures coming from a specification error. There are numerous studies that emphasize the risk that the specification error will seriously bias an estimate and thereby lead to a spurious result. Engle et al. (1986), for instance, point out that parametric methods would bring out an incorrect sign on an important variable. Gallant, Hsieh and Tauchen (1991) argue that a parametric specification such as ARCH/GARCH model might lead an empirical analysis to wrong findings of nonlinearity over and above the second moments that are clearly revealed in a non-parametric analysis in exchange rate data. Engle and Gonzales-Rivera (1991) empirically analyze the same data as Gallant, Hsieh and Tauchen — pound/dollar exchange rate — and confirm that a parametric analysis might miss side lobes in the error density of an exchange rate, which are clearly captured in a non-parametric analysis.

1. Trading Volume Theory

The foreign exchange market is the largest and fastest-growing financial market with daily turnover in the world. The estimated daily trading volume in global foreign exchange markets reached $1,500 billion in April 1998, which is more than 100 times as large as trade flows. Yet, exchange rate models have little to say about volume, much less the degree to which volume conveys useful information. In traditional macro approach, asset prices adjust every period to make agents content with the specified amount of assets in their portfolios. The adjustment of asset prices instantaneously reflects the arrival of new information in the marketplace, which all participants observe and interpret in the same way. Hence, the basic macroeconomic model of the exchange rate implies all information pertaining to the current and future fundamental determinants of exchange rates. In addition to the lack of economic models, the unavailability of spot volume data at reasonable high frequencies is a principal handicap for many foreign exchange time-series analyses.

Market microstructure theory is especially interested in analyzing how specific trading mechanism affects the price formation process. The study of market microstructure has already found one empirical regularity: the positive correlation between trading volume and volatility. Frankel and Froot (1990), for example, found evidence by using survey data that trading volume and exchange rate volatility are positively related. Grammatikos and Saunders (1986) and Jorion (1996) analyze foreign currency futures contracts and find that de-trended volume is positively related to variability. An obvious drawback in these studies is that trading in futures is very small compared to OTC volumes. The positive relationship between spot and futures volumes may be quite different in their overall behavior. Foreign exchange market turnover growth, for example, slowed down considerably in the late 1980s, while forward turnovers continued to grow vigorously. The other problem is that the choice of futures volumes may also induce an omitted-variable problem in the estimation as pointed out by Dumas (1994).

Hartmann (1998) uses the triennial foreign exchange trading volume reported in BIS survey[1] by combining a large cross-section of exchange rate with volume into a panel. However, the analysis faces the problem of having limited time series information.

Hartmann (1999) uses a new eight-year long daily volume series for the dollar/yen spot market analysis. In Japan, all foreign exchange brokers have to report their trading volume in yen/dollar to the Bank of Japan. Wei (1994) has also used the same data

[1] See BIS publication titled "Central Bank Survey of Foreign Exchange and Derivatives Market Activity."

source but he selected only one daily observation per month to see the relationship between volatilities and bid-ask spreads. These data have also some drawbacks; they could be affected by changes in the share of brokered deals in the total trading. Moreover, the broker volume might still be slightly different from the direct inter-dealer volume: dealers tend to turn to brokers for larger transactions because anonymity for larger deals is more important than for smaller ones. Also, since the yen is an internationalized currency traded around 24 hours throughout the world, the data represent a very small fraction of the global yen/dollar market.

Lyons (1995) looks at high-frequency data on actual transactions in the OTC market. The transaction data including information on the direction of order flows was obtained by observing a foreign exchange dealer in New York in one week in 1992. A shortcoming of the research is that it covers only a limited segment of foreign exchange markets and spans a relatively short-time period.

Galati (2000) uses what is similar to the data set of this study, daily trading volume for the dollar exchange rates of seven currencies, currencies of Brazil, Colombia, India, Indonesia, Israel, Mexico and South Africa, and finds that in most cases volume and volatility are positively correlated, which is an indication that they both react to unobserved common factors. However, the investigation neither covers the Korean exchange rate market nor analyzes the effects of liberalization, all of which are the main focus of this chapter.

A theoretical explanation of the positive relationship between trading volume and volatility is that both variables are driven by the arrival of new information as in mixture distribution model, which elaborates on Clark (1983), Epps and Epps (1976), and Tauchen and Pitts (1983). In this model, the joint distribution of daily price changes and transaction volumes of an asset is derived from a model of intraday equilibrium price changes and intraday volumes. New information during the day causes traders to update their reservation prices and demand or supply of an asset until the average of their individual reservation prices clear the market again. If they disagree on the interpretation of the new information, then the respective equilibrium price change comes with high transaction volume, while relative unanimity results in a price change with little volume. More formally, market prices P and volume V are modeled as:

$$\begin{aligned} \Delta P &= s_1 \sqrt{I}\, z_1, \\ V &= m_2 I + s_2 \sqrt{I}\, z_2, \end{aligned}$$

where z_1 and z_2 are independent $N(0,1)$ variables, and I represents the random number of daily equilibria, on account of the new information arriving at the market. The mean m_2 and the standard deviation s_2 of intraday volumes are both increasing functions in trader disagreement as measured by the standard deviation of individual trader's reservation price update due to the arrival of new information.

2. SNP Estimation of the Conditional Density

Let y_t be the observed data with dimension M and have a Markovian structure as follows. Markovian structure means that the conditional density of y_t given the entire past $(y_{t-1}, y_{t-2}, \ldots)$ depends on L lags from the past. Denote the one-step ahead conditional density of y_t as $f(y_t \mid x_t)$, where $x_t = (y'_{t+1-L}, y'_{t+2-L}, \ldots, y'_t)'$, which is a vector of length $M \cdot L$. Given the past of y_t, one can determine the conditional density $f(y_t \mid x_t)$ by minimizing

$$s_n(q) = -\frac{1}{n}\sum_{t=1}^{n} f(y_t \mid x_t, q).$$

The SNP method is a semi-parametric density estimation based on an approximation of $f(y_t \mid x_t)$ with Hermite series expansion. That is,

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

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

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

Nychka, 1987). The tuning parameter K_z controls the extent to which the model deviates from normality.

To approximate conditionally heterogeneous processes, one can applied as above, except letting each coefficient of the polynomial be a polynomial of degree K_x in x. Therefore, the shape of the density depends on x when K_x is positive. All moments, thus, can depend on x and the density can approximate any form of conditional heteroskedasticity (Gallant, Hsieh and Tauchen, 1989). The tuning parameter K_x controls the extent to which the model' s deviations from normality vary with the history of the process.

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

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

$$\mathrm{vech}(R_{x_{t-1}}) = \boldsymbol{r}_0 + \sum_{i=1}^{L_r} P_{(i)} \left| y_{t-1-L_{r+i}} - m_{x_{t-2-L_r+i}} \right| + \sum_{i=1}^{L_g} \mathrm{diag}(G_{(i)}) R_{x_{t-2-L_g}+i}$$

where vech(R) denotes a vector of length M(M+1)/2 containing the elements of the upper triangle of R, $\boldsymbol{r}_0$ is a vector of length M(M+1)/2, $P_{(1)}$ through $P_{(L_r)}$ are M(M+1)/2 by M matrices, and $|y-m|$ denotes a vector containing the absolute values of $(y-m)$. The classical GARCH has $\Sigma_{x_{t-1}}$ expressed in terms of squared lagged residuals and lagged values of $\Sigma_{x_{t-1}}$. Therefore, the SNP version of GARCH is more akin to the suggestions of Nelson (1991).

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

<Table III-1> SNP Models

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

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

3. Impulse Response Analysis of Nonlinear Models

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

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

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

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

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

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

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

for $x^+ = x + \boldsymbol{d}$, and

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

for $x^- = x - \boldsymbol{d}$, j=1,…,J. Accordingly, the positive and negative impulse responses of the J-step conditional mean are $\left\{\hat{y}_j^+ - \hat{y}_j^0\right\}_{j=1}^J$ and $\left\{\hat{y}_j^- - \hat{y}_j^0\right\}_{j=1}^J$, respectively. These two terms provide a nonlinear impulse response function for shocks on the conditional mean of the system.

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

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

for $j = 1,2,\ldots$, where $x = (y'_{-L+1}, \ldots, y'_0)'$. The positive and negative impulse responses of perturbations δ on the volatility are $\left\{\hat{V}_j^+ - \hat{V}_j^0\right\}_{j=1}^J$ and $\left\{\hat{V}_j^- - \hat{V}_j^0\right\}_{j=1}^J$, respectively. In our application, $f^j(y \mid x)$ is approximated by SNP in place of $f(y \mid x)$.

4. Data and Estimation Results

The data consist of daily won/dollar spot exchange rates and trading volumes from January 3, 1995 to June 20, 2000, totaling 1,371 observations. Trading volumes, as explained in chapter II, are the size of inter-dealer transactions via two brokers — KFTC or KMBC. The spot exchange rates have been obtained from Bloomberg. For empirical analysis, we divide the overall period into pre- and post-liberalization periods. The pre-liberalization period covers from January 4, 1995 to September 30, 1997 and the other period from April 1, 1999 to August 31, 2000.

Even though data are available from March 1, 1990, the date on which Korea adopted the market average exchange rate system, empirical analyses are restricted to cover years from 1995 due to the possibility of structural breaks or change of regime in the foreign exchange market. Joo and Kim (1999) argue that movements of the exchange rates were explained with macroeconomic fundamentals after 1995, which is not the case from 1990 to 1995, and that the exchange rates seem to exhibit structural breaks statistically since 1995. The time coincides with some noticeable efforts by the Korean government for capital account liberalization, such as easing limits on stock investment for non-state owned companies by foreigners from 10 to 12% and opening non-guaranteed convertible bonds issued by small and mid-size companies. Furthermore, Standard & Poor's, a credit rating agency, has upgraded Korea's sovereign credit rating from A2 to A1 in May 1995, which resulted in net capital inflows, expansionary monetary policy and the won depreciation. The starting point of post-liberalization period coincides with the effective date of the first phase of foreign exchange liberalization. The last date of post-liberalization period is dictated by the availability of the data.

<Table III-2> Basic Statistics

	KRW/USD		Volume	
	Pre-lib.	Post-lib.	Pre-lib.	Post-lib.
Mean	2.27×10^{-2}	-2.86×10^{-2}	7.368	7.921
Max	1.639	1.508	8.463	8.576
Min	-2.238	-1.557	6.259	6.859
Standard Deviation	0.313	0.377	0.352	0.259
Skewness	-4.25×10^{-2}	-5.95×10^{-2}	0.152	-0.432
Kurtosis	7.667	3.065	-7.35×10^{-2}	0.559
r_1	-8.96×10^{-2}	0.512	-1.32×10^{-2}	0.628
r_2	3.31×10^{-2}	0.413	-0.122	0.500

Note: r_i ’s are the auto-correlation of an order i.

We adjust the raw data for systematic calendar and crisis effects. Since previous empirical studies documented day of the week and monthly effects, we use various dummies to remove these systematic effects. After removing seasonal effects, we then adjust re-scaled log first-differences of the exchange rates and log volume. It is common way to take log for various financial variables. The motivation of log volume is to stabilize variance of volume to lessen the burden on the non-parametric procedures. To perform the adjustment to log difference or log volume, we first run the following regression:

$$y = x'b + u \text{ (mean equation),}$$

where y is the series to be adjusted and x is the set of adjustment regressors as described above. We then take the least squares residuals from the mean equation to construct a variance equation:

$$\log(u^2) = x'g + e \ .$$

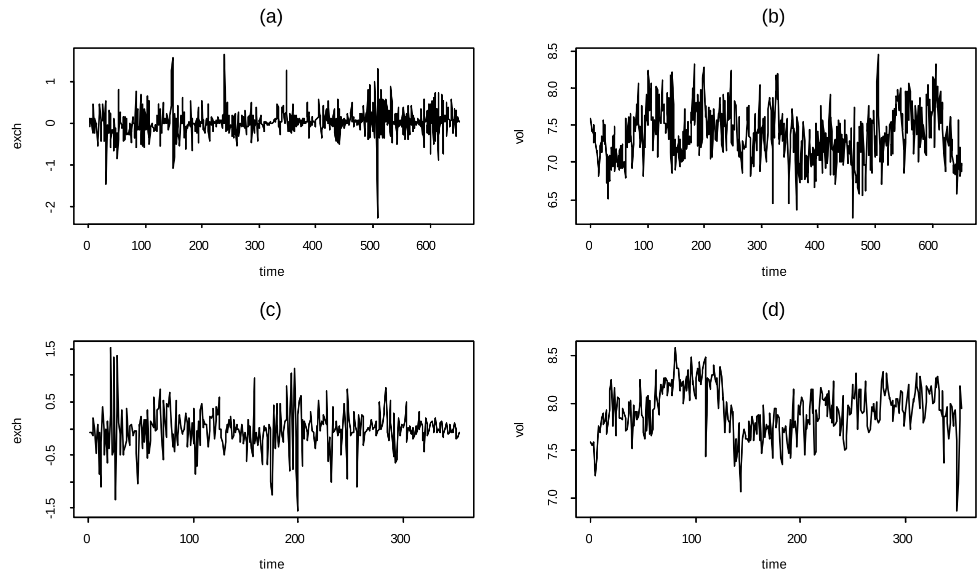
This regression is used to standardize the residuals from the mean equation, then a final linear transformation is performed to create adjusted y:

$$y_{adj} = a + b\left(\frac{\hat{u}}{\exp(x'\hat{g}/2)}\right)$$

where a and b are chosen such that the sample means and variances of the data are the same before and after the adjustments for easing economic interpretation.

The SNP estimation results are presented in Tables III-7 and III-8. The model selected under the Schwarz criterion for both periods is commonly $L_m = 2$, $L_g = L_r = 1$, $K_z = 4$, $K_x = 3$, $I_z = I_x = 0$. The model has two lags in the linear autoregressive component, GARCH(1,1), and a non-Gaussian error structure reflected by the fact a polynomial of degree 4 in z is selected. In both periods, the density is GARCH model with a non-parametric error density.

<Figure III-1> Adjusted Data



Note: (a), (b) are plots of daily observations on the growth rate of the won/dollar exchange rate and the trading volume before the liberalization. (c), (d) are counterparts of (a) and (b) after the liberalization, respectively.

<Table III-3> Bivariate SNP Estimation (pre-liberalization)

L_u	L_g	L_r	L_p	K_z	I_z	K_x	I_x	P	S_n	BIC
1	0	0	1	0	0	0	0	9	2.6922	2.7377
2	0	0	1	0	0	0	0	13	2.6702	2.7358
3	0	0	1	0	0	0	0	17	2.6614	2.7472
4	0	0	1	0	0	0	0	21	2.6536	2.7595
5	0	0	1	0	0	0	0	25	2.6483	2.7745
2	1	1	1	0	0	0	0	22	2.5599	2.6709
2	***1***	***1***	***1***	***4***	***3***	***0***	***0***	***30***	***2.4521***	**2.6035**
2	1	1	1	4	2	0	0	31	2.4507	2.6072
2	1	1	1	4	1	0	0	33	2.4505	2.6070
2	1	1	1	4	3	1	0	48	2.4196	2.6619

Note: 1) L_i's lag length for μ=(mean), g=(GARCH), r=(ARCH), p=(polynomial) and (K_z , K_z) are polynomial degrees in (z, x).

2) P_q is the number of free parameters in the model.

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

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

<Table III-4> Bivariate SNP Estimation (post-liberalization)

L_u	L_g	L_r	L_p	K_z	I_z	K_x	I_x	P	S_n	*BIC*
1	0	0	1	0	0	0	0	9	2.6922	2.7357
2	0	0	1	0	0	0	0	13	2.6702	2.7358
3	0	0	1	0	0	0	0	17	2.6614	2.7472
4	0	0	1	0	0	0	0	21	2.6536	2.7595
5	0	0	1	0	0	0	0	25	2.6483	2.7745
2	1	1	1	0	0	0	0	22	2.4170	2.6057
2	***1***	***1***	***1***	***4***	***3***	***0***	***0***	***30***	***2.3089***	***2.5661***
2	1	1	1	4	2	0	0	31	2.3037	2.5694
2	1	1	1	4	1	0	0	33	2.2988	2.5817
2	1	1	1	4	3	1	0	48	2.2664	2.6778

Note: 1) L_i*'s* lag length for μ=(mean), g=(GARCH), r=(ARCH), p=(polynomial) and (K_z , K_z) are polynomial degrees in (z, x).

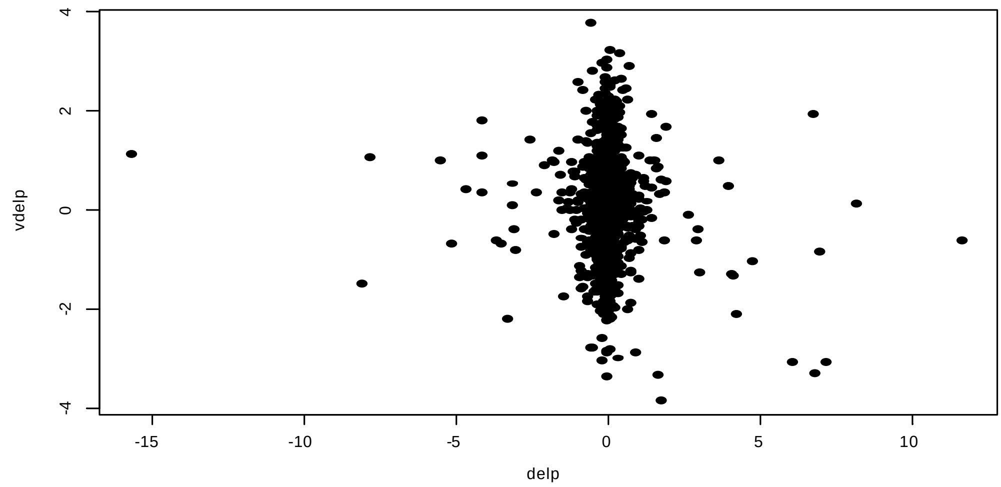
2) P_q is the number of free parameters in the model.

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

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

Figure III-2 is a scatter plot of the data, (Δp_t , v_t), in overall periods which clearly reveals the contemporaneous volume-volatility relationship. The shape of the point cloud shows that days with small volatility tend to be days with lower-than-average volume, while days with large price volatility are high volume days.

<Figure III-2> Plots of the Price-Volume Relationship



Note: The panel is a scatter plot of standardized adjusted log volume, denoted as $vdelp = (v_t - \bar{v}) / s_v$, against Δp_t, which is also expressed in units of unconditional standard deviation. One standard deviation of v_t, equals 0.457. One standard deviation of Δp_t, equals 1.402.

The figure is a useful guide for defining shocks to exchange rate and volume that are consistent with the historical range of the data. We investigate the effects of three different types of shocks that are designed by inspection of the scatter plot to generate different combinations of some typical and realistic perturbations. That is, we design shocks to come close to tracing out the extreme edges of the point cloud in Figure III-2. In particular, the scatter plot suggests that the following design, with three types of error shocks labeled *A*, *B*, and *C*, is typical of the variation of the data[2]:

---

[2] Since the trading volume and the exchange rates are measured in units of unconditional standard deviation and in percentage, respectively, we implement the first with standard deviations and the latter do with percent deviation above their unconditional means.

$$
\begin{aligned}
dy_A^{+} &= (\ \ 5.0,\ \ 3.0)',\\
dy_A^{-} &= (-5.0,\ \ 3.0)',\\
dy_B^{+} &= (\ \ 5.0,\ \ 0.0)',\\
dy_B^{-} &= (-5.0,\ \ 0.0)',\\
dy_C^{+} &= (\ \ 0.0,\ \ 3.0)',\\
dy_C^{-} &= (\ \ 0.0,\ -3.0)'.
\end{aligned}
$$

The A shocks are combined price-volume shocks where the price movements are ±5.0 percent and volume is 3 standard deviations above its unconditional mean. The B shocks are pure price shocks of ±5 percent with volume pinned at its mean. Finally, the C shocks are pure volume shocks of ±3 standard deviations with no price movements.

Three different shocks can be interpreted within the framework of recent developed theoretical work in the stock market such as Blume, Easley and O' Hara (1994). Even though their model analyzes the stock market rather than the foreign exchange market, the noisy trading model also serves as very useful guidance for the latter. Based on such view, the A shocks reflect the situation which postulates how private information would disseminate in the market. The noisy trading model postulates that information is diffused and incorporated into prices (exchange rates) through the trading of informed investors. The uninformed traders infer a new piece of information via the trading volume. Therefore, the trading process diffuses the information as the new piece of information arrives, resulting in a price movement on higher than normal volume. This private information shock can be empirically implemented with the A shocks. When the piece of information is common knowledge, the exchange rate would fluctuate around the average trading level. Our B shock is designed to capture this situation. The positive C shock represents the situation where no consensus has been reached among traders and trade, therefore, occurs due to disparate beliefs. The negative C shock is included for symmetry.

We now turn to the results of nonlinear impulse response analysis for three shocks. Figures III-3 and III-9 depict the effects of the A shocks on the means of two variables before and after the liberalization. The conditional means of spot and volume dampen after ten days of both periods even though the degree of fluctuations is more severe before the liberalization. However, impulse responses of the exchange rate to private information shocks before the liberalization are much slower than those of after the liberalization. One noticeable thing before the liberalization is a kind of more prolonged long-memory, i.e., positive and negative shocks do not completely die out or dampen back towards the baseline after 40 days.

The leverage effect — asymmetry of the volatility response — does not happen during the first seven or eight days as seen in Figure III-4. However, both positive and negative shocks cause the volatility of the exchange rate to deviate from the baseline by more than 50 days. The shocks also bring out a markedly huge hump after 20 days for negative shocks or 30 days for positive shocks. This means that the positive shock increases the volatility of the exchange rate much slower than the negative shock. After the liberalization, the impulse response of volatility to A shocks shares a very similar shape with the one before the liberalization except for the mild hump shape as seen in Figure III-10. There is no leverage effect up until around ten days and the deviation of both shocks from the baseline is larger in the short run — within ten days — than 30 or 40 days. The "delayed leverage effect" is a very interesting finding in the won/dollar exchange market because the transient leverage effect is a common empirical finding in financial variables. For the impulse response of volume volatility as seen in the panel

(b) of Figures III-4 and III-11, the shocks quickly die out even though there are minor long-term effects.

The impulse response of means to the B shocks (common knowledge shocks) before the liberalization shows that the levels of the exchange rates are hardly affected by the shocks within ten days as shown in Figure III-5. However, the negative shocks cause the means of the exchange rate to deviate from the baseline after around 25 days. Moreover, the difference between the baseline and positive shocks is maximized after 40 days. For the trading volumes, both shocks are symmetric within a very short time (one or two days) but they deviate from the baseline by more than 50 days. After the liberalization, the response of means to the B shocks exhibits very similar phenomena except for one thing. The general trend of the baseline shows upward trends after the liberalization but it shows downward trends before the liberalization. These facts reflect that the spot exchange rate on average depreciate after the liberalization and vice versa before the liberalization. These results are consistent with the situation of Korea's economy. The economy experienced a shock from large negative terms of trade in the second quarter of 1996, which created a significant depreciation pressure on the Korean won just before the crisis. On the contrary, the exchange rate has consistently appreciated due to capital inflows or regaining of confidence in the economy.

Since the absolute magnitudes of the B shocks — deviations of both shocks from the baseline — are much smaller than those of the A shocks, we acknowledge that the interpretation should be given very cautiously and further investigation of statistical works such as visualization of confidence bands is needed.

As shown in Figures III-6 and III-12, the impulse responses of the exchange rate volatility to the B shocks are very similar to those to the A shocks, except reactions within a very short horizon either before or after the liberalization. The absolute difference between the baseline and either the positive or negative shocks is highly comparable to the case of the A shocks. However, the common knowledge shocks do not cause both shocks to deviate from the baseline, which is not the case for the A shocks. The difference, therefore, tells that private information shocks or disparate beliefs cause the exchange rate volatility to increase in a very short run. That is, the exchange movement itself, either depreciation or appreciation shocks, does not on average increase the volatility. The volatility, however, does not come toward the baseline for the common knowledge shocks even after 50 days, which resembles the reaction of A shocks.

The fact that the absolute magnitude of the mean deviation of both shocks from the baseline is small indicates that the impulse responses by pure volume movements are responsible for the mean responses. This conjecture is visualized in Figures III-7 and III-8. Surprisingly, the shape of responses by the A shocks are almost the same as those by the C shocks before and after the liberalization. By inspecting the conditional mean and volatility profiles manually, we found that there are slight differences with ten to minus three to seven digits. We can argue two things with this fact. One, the impulse response of the spot exchange rate means to the B shocks might not be statistically significant, which needs further empirical investigation. Therefore, any shocks without accompanying volume movements make the level of the exchange rate deviating from its average level very small in magnitude. The same is true for the level of trading volumes. Two, the volatility of the exchange rate is affected by the volume shocks and the exchange rate shocks with the almost same magnitude after ten days for both periods. The exchange rate shocks are responsible for very short-term (less than ten days) volatility in the level of the exchange rate.

Our empirical results reveal several distinguished main characteristics after the change in institutional setting. First, asymmetry of the exchange rate level is attenuated and both shocks are more transient phenomena after the liberalization. As can be seen in panel (a) in Figures III-3 and III-9, the mean of the exchange rate caused by the depreciation shocks approaches the baseline more slowly than by the appreciation shocks before the liberalization. Also, both private information shocks have relatively more prolonged effects on the level of the exchange rate before rather than after the liberalization. With this difference, we cautiously argue that the exchange rate market becomes more efficient due to the quick dissipation of private information after the liberalization.

Here are two possible reactions to the statement. Does private information exist in the foreign exchange market? How would the market be efficient if economic agents gained profits using the bits of private or good quality information? The first question is based on a rationale that individual analysts in the equity market have information on individual corporations but that is not the case in the foreign exchange market. There are a couple of papers regarding the first issue. Lyons (1995) argues that the bits of information — customer order flows — affect a market maker's quote.[3] Dominguez (1999) also presents evidence that some traders know a central bank's intervention before it becomes public information. Ito, Lyons and Melvin (1998) provide empirical evidence supporting the existence of private information in the foreign exchange market.

[3] Since the won/dollar exchange market is not an inter-dealer market but a centralized broker market, it seems to be unreasonable for any market participant to be able to observe customer order flows. However, if the market maker is Korean authority actively involved in foreign exchange transactions, we believe that the argument is not highly applicable to the market.

The second reaction can be vitiated using asymmetric information theory, a main branch of microstructure theory.[4] The term “efficient” does not mean that there is no arbitrage trading profits opportunity as implied by a rational expectation auction model, where all agents are homogenous and all information is instantly reflected in the market price. This representative agent model cannot provide the economic rationale for the trading volume; volume emerges as the result of traders’ optimal demands, but it does not play any role other than market clearing. Rather, the term should be interpreted based on a microstructure perspective in which market participants are composed of informed traders and uninformed traders (or more precisely, less informed traders). The difference between the two types of traders is that informed traders can aggregate various pieces of information available in the market in a relatively rapid and cheap way. Within the market microstructure framework, it is possible for informed or skillful traders to enjoy positive profits at the expense of uninformed traders who actively participate in a transaction to eliminate exposure.[5]

We now go back to the similarity and difference in the foreign exchange market before and after the liberalization. As seen in panel (a) of Figures III-8 and III-14, both volume shocks cause the conditional volatility of the exchange rate to increase in the sense that the responses are located above the baseline. Both periods show that the volatility responses of the exchange rate to both shocks are sluggish and persistent.

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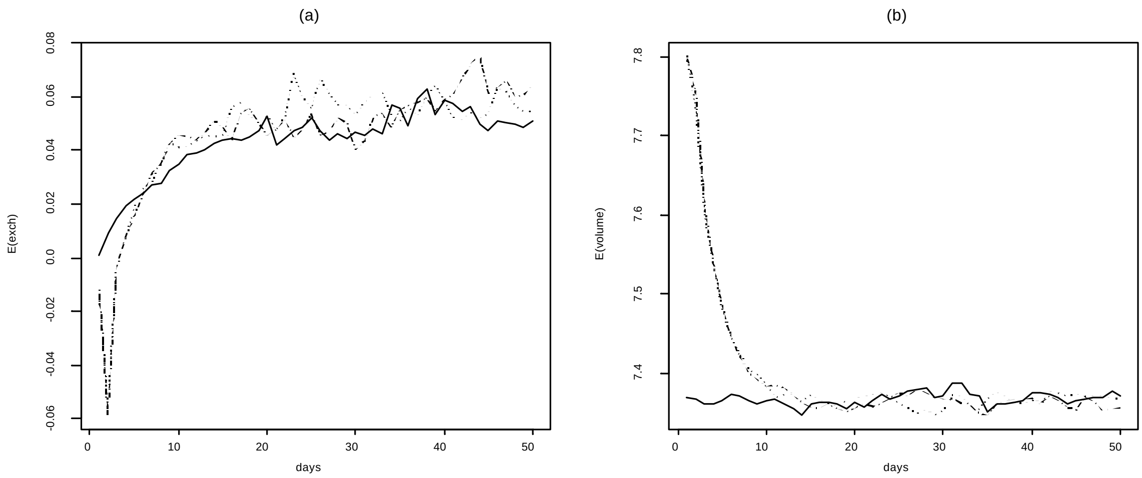
[4] The other main branch is the inventory-control theory where traders modify bid-ask spreads so as to discourage further exposure in that direction.

Therefore, one interesting empirical finding is that the trading volume leads volatility in the exchange rate to be persistent. In some sense, the trading volume generates “excessive volatility” caused by trading based on noise or fads rather than news or economic fundamentals. One difference after the liberalization, however, is that the volume shocks affect the volatility in a less prolonged way. The volume shocks, representing heterogeneity of beliefs, generate more excessive volatility, at least in comparison to the magnitude of total deviations from the baseline and to the more volatile features as time passed, before the liberalization than after the liberalization. Hence, the degree of excessive volatility decreases after the liberalization even if both periods exhibit excessive volatility generated by the trading volume. This empirical finding leads us to conclude that the post-liberalization foreign exchange market is now working in a much more desirable way.

<Figure III-3> Impulse Response of Means to the A shocks (pre-liberalization)



Note: Plotted in the left (right) panel is the impulse response of spot (volume) means to the A shocks. In each panel, the solid line is the baseline, the heavy dotted line corresponds to a positive A shock, and the light dotted line corresponds to a negative A shock.

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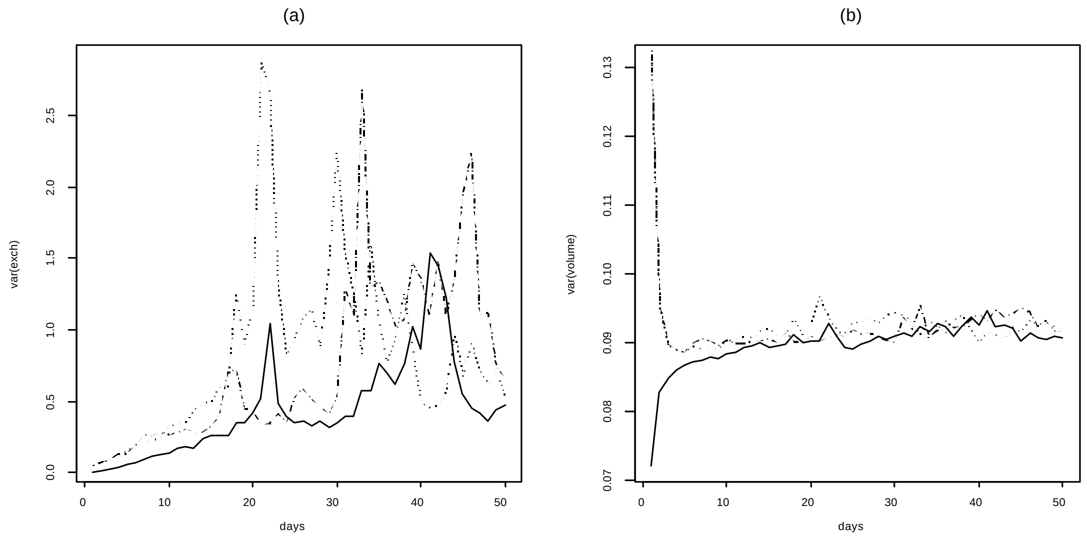
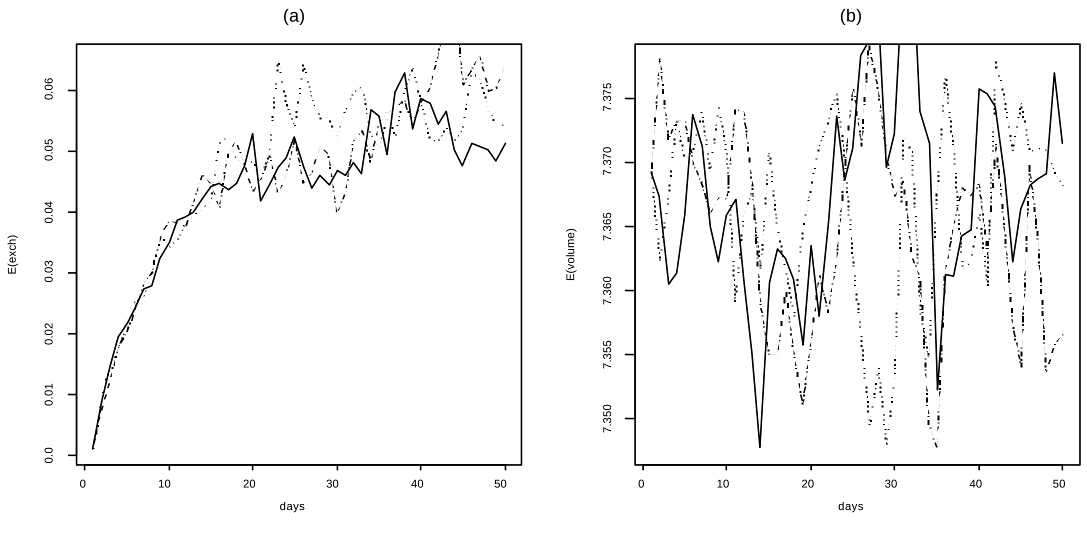
[5] See Frankel, Galli, and Giovannini (1996), p. 4.

<Figure III-4> Impulse Response of Volatility to the A Shocks (pre-liberalization)



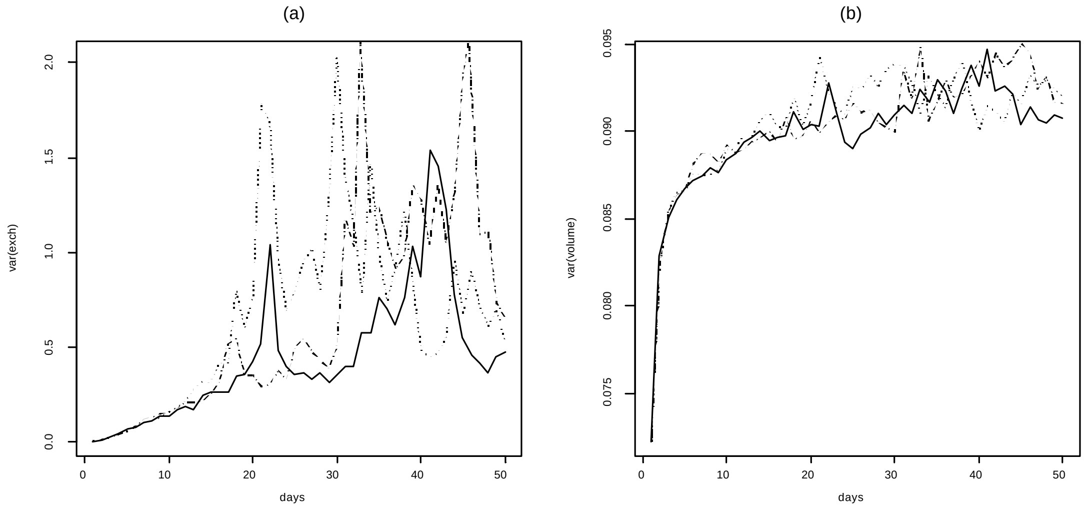
Note: Plotted in the left (right) panel is the impulse response of spot (volume) volatility to the A shocks. In each panel, the solid line is the baseline, the heavy dotted line corresponds to a positive A shock, and the light dotted line corresponds to a negative A shock.

<Figure III-5> Impulse Response of Means to the B shocks (pre-liberalization)



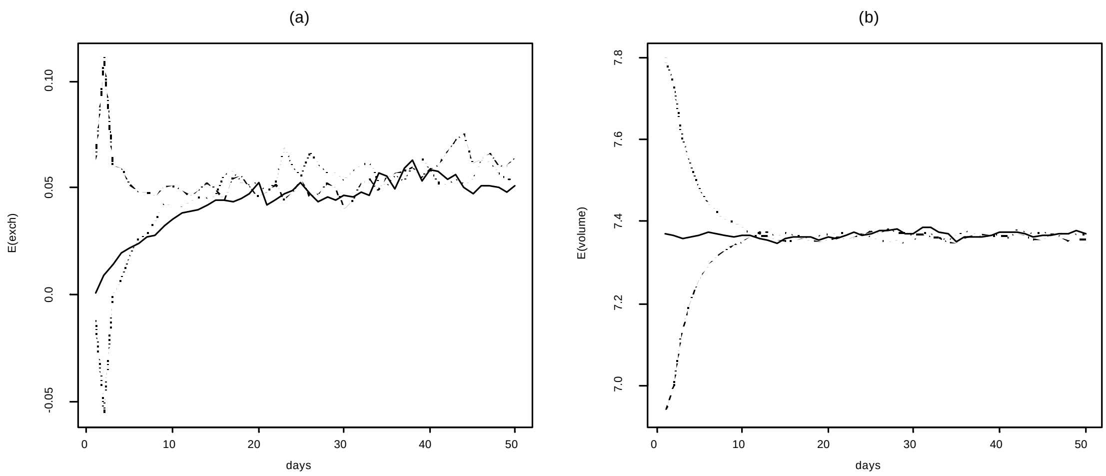
Note: Plotted in the left (right) panel is the impulse response of spot (volume) means to the B shocks. In each panel, the solid line is the baseline, the heavy dotted line corresponds to a positive B shock, and the light dotted line corresponds to a negative B shock.

<Figure III-6> Impulse Response of Volatility to the B shocks (pre-liberalization)



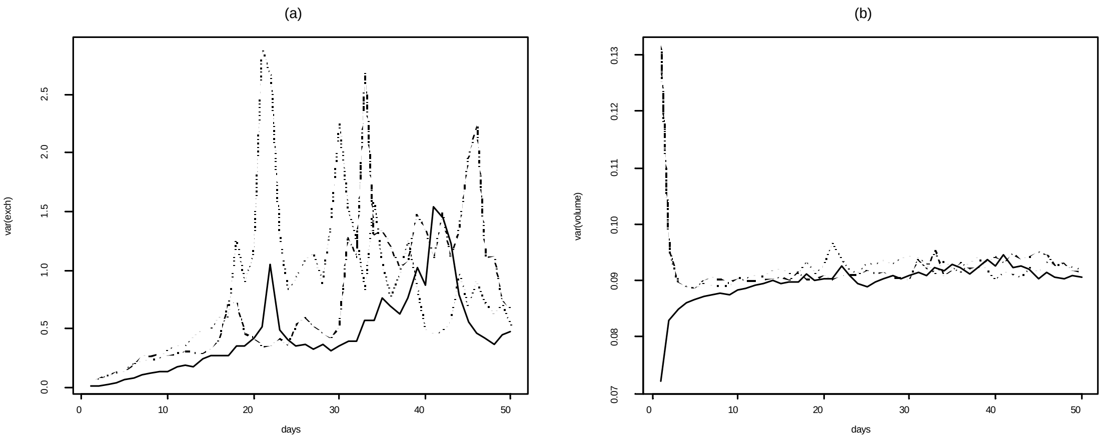
Note: Plotted in the left (right) panel is the impulse response of spot (volume) volatility to the B shocks. In each panel, the solid line is the baseline, the heavy dotted line corresponds to a positive B shock, and the light dotted line corresponds to a negative B shock.

<Figure III-7> Impulse Response of Means to the C shocks (pre-liberalization)



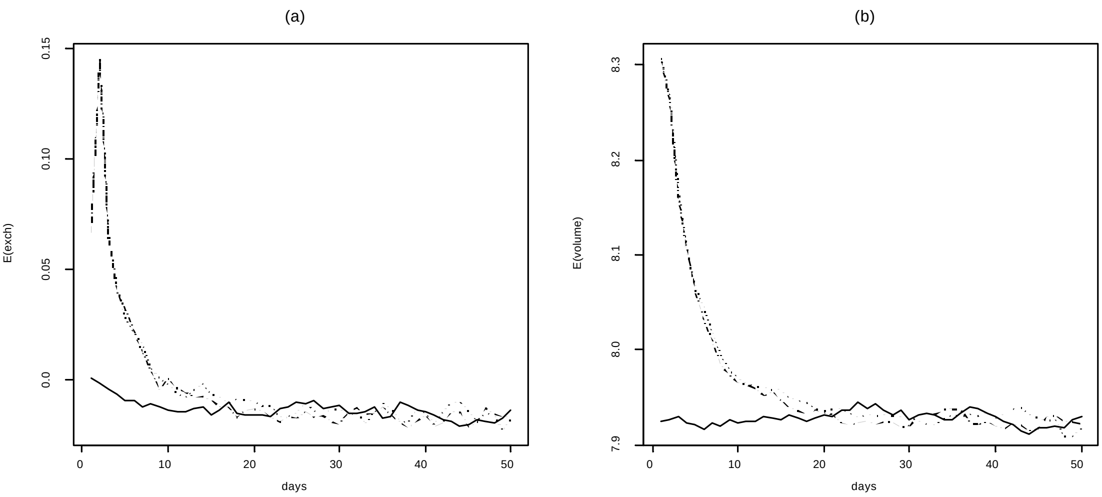
Note: Plotted in the left (right) panel is the impulse response of spot (volume) means to the C shocks. In each panel, the solid line is the baseline, the heavy dotted line corresponds to a positive C shock, and the light dotted line corresponds to a negative C shock.

<Figure III-8> Impulse Response of Volatility to the C shocks (pre-liberalization)



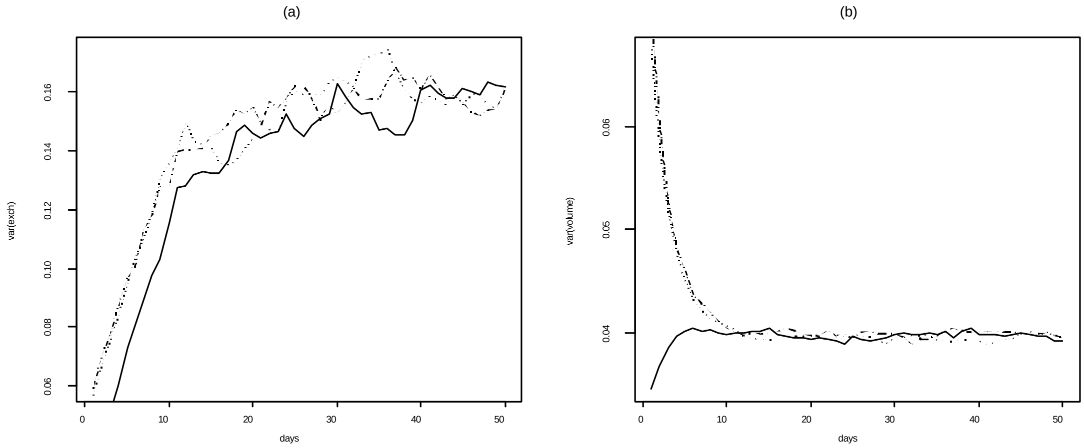
Note: Plotted in the left (right) panel is the impulse response of spot (volume) volatility to the C shocks. In each panel, the solid line is the baseline, the heavy dotted line corresponds to a positive C shock, and the light dotted line corresponds to a negative C shock.

<Figure III-9> Impulse Response of Means to the A shocks (post-liberalization)



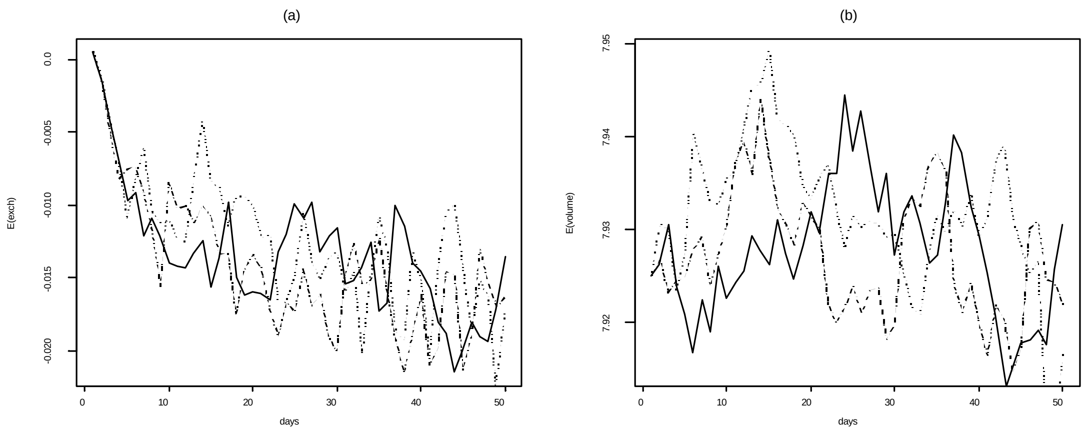
Note: Plotted in the left (right) panel is impulse response of spot (volume) means to the A shocks. In each panel, the solid line is the baseline, the heavy dotted line corresponds to a positive A shock, and the light dotted line corresponds to a negative A shock.

<Figure III-10> Impulse Response of Volatility to the A shocks (post-liberalization)



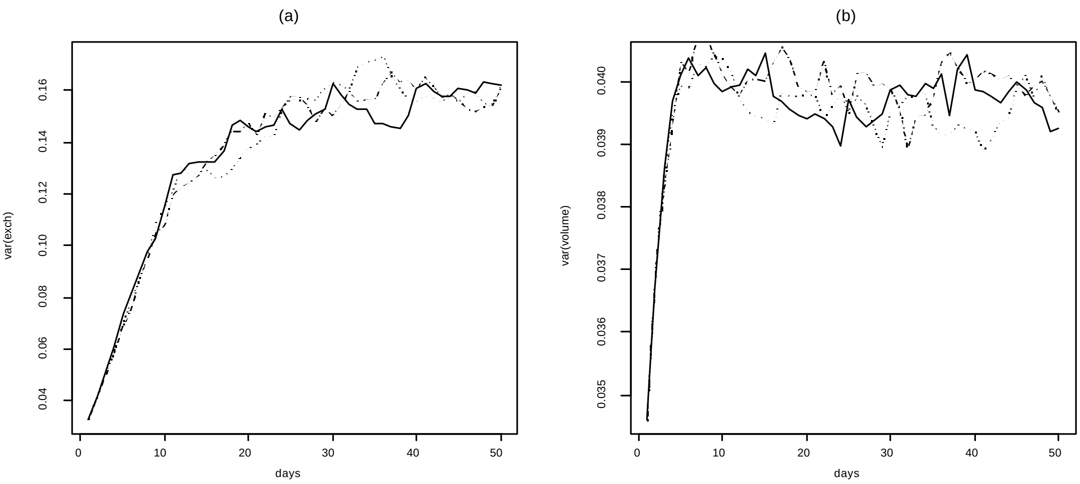
Note: Plotted in the left (right) panel is impulse response of spot (volume) volatility to the A shocks. In each panel, the solid line is the baseline, the heavy dotted line corresponds to a positive A shock, and the light dotted line corresponds to a negative A shock.

<Figure III-11> Impulse Response of Means to the B shocks (post-liberalization)



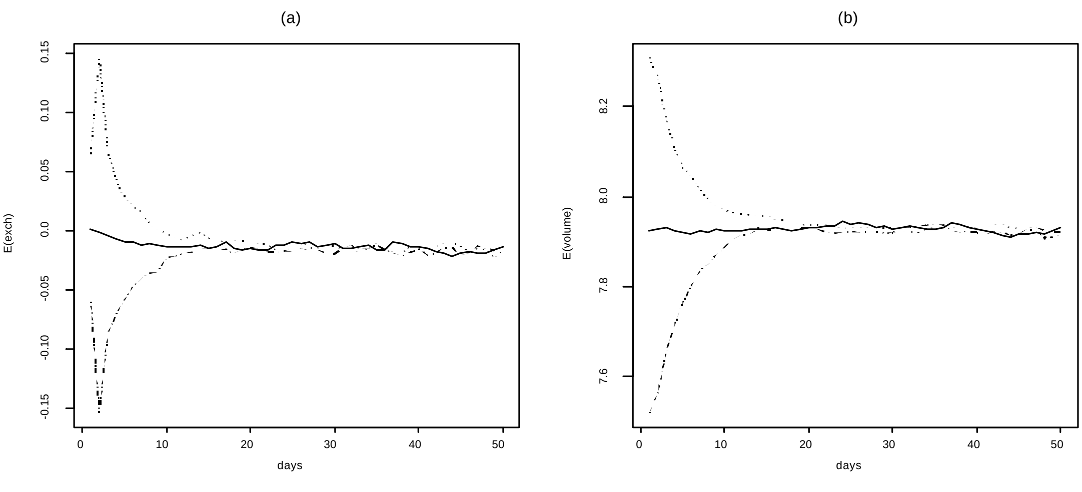
Note: Plotted in the left (right) panel is impulse response of spot (volume) means to the B shocks. In each panel, the solid line is the baseline, the heavy dotted line corresponds to a positive B shock, and the light dotted line corresponds to a negative B shock.

<Figure III-12> Impulse Response of Volatility to the B shocks (post-liberalization)



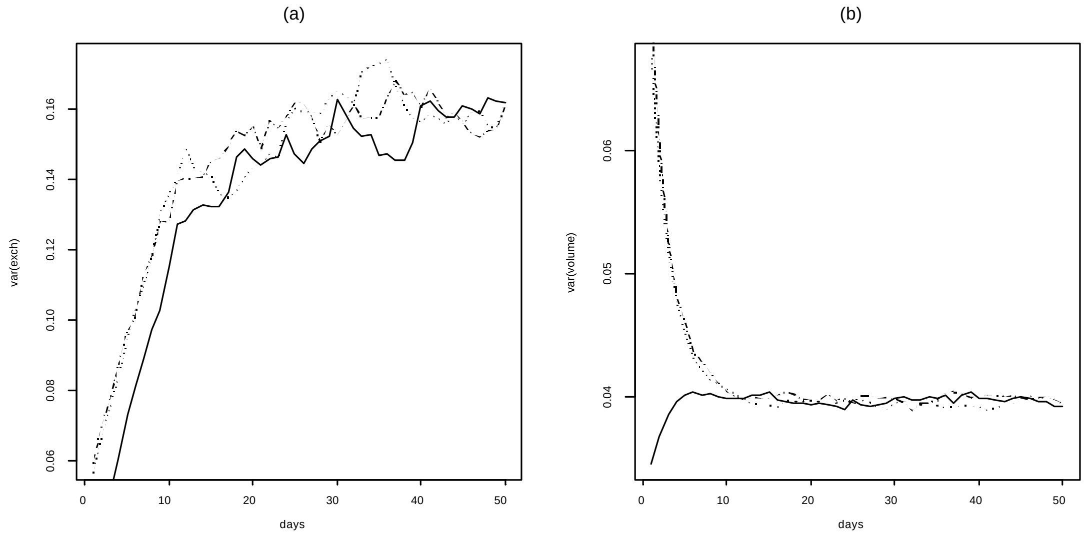
Note: Plotted in the left (right) panel is impulse response of spot (volume) volatility to the B shocks. In each panel, the solid line is the baseline, the heavy dotted line corresponds to a positive B shock, and the light dotted line corresponds to a negative B shock.

<Figure III-13> Impulse Response of Means to the C shocks (post-liberalization)



Note: Plotted in the left (right) panel is impulse response of spot (volume) means to the C shocks. In each panel, the solid line is the baseline, the heavy dotted line corresponds to a positive C shock, and the light dotted line corresponds to a negative C shock.

<Figure III-14> Impulse Response of Volatility to the C shocks (post-liberalization)



Note: Plotted in the left (right) panel is impulse response of spot (volume) volatility to the C shocks. In each panel, the solid line is the baseline, the heavy dotted line corresponded to a positive C shock, and the light dotted line corresponds to a negative C shock.

IV. Testing Efficiency by NDF Exchange Rates

This chapter describes the effect of the foreign exchange market liberalization, examines the changes in the Non-Deliverable Forward (NDF) market and analyzes the structural changes in the foreign exchange market. After the liberalization, the forward market is expected to utilize more information, not only for increasing participants, but also for changing the market structure. Moreover, risk imposed in the market is expected to play an important role in increasing the efficiency of the domestic foreign exchange market, since the market has utilized more information and the floating exchange rate regime has been adopted. The efficiency in the foreign exchange market will be investigated in this context.

1. Brief Description of the NDF Market

Since the NDF exchange market is not popular in most developed financial markets, it is much more informative to understand the features of the non-deliverable won/dollar forward (NDF) market. The NDF market has been naturally created by foreign investors engaged in transactions with Korean financial institutions. Until May 1999, Korea's only forward exchange market was the domestic forward market, which consisted of onshore transactions between two transaction parties. The futures market, which allows transactions between multiple sellers and buyers, did not exist. Therefore, there was no means of avoiding the risk inherent in foreign exchange transactions.

The absence of a futures exchange market led foreigners, or more precisely nonresidents, to create their own means of transaction in the form of offshore NDF markets. Such markets first appeared around 1996 in Hong Kong and Singapore to remove exchange risks associated with the foreigners' portfolio investment in Korea. Currently, several brokerage houses including Prebon Yamane, the biggest broker, are functioning in the Hong Kong/Singapore offshore won/dollar NDF markets, while many large investment banks including Citibank, Chase, and JP Morgan are participating in the interbank market. The Hong Kong/Singapore offshore NDF markets also host transactions in other currencies, such as Taiwanese dollars, Chinese yuan, Philippine pesos and Indian rupees, but the greatest flows have been made in the Korean won.

An NDF contract is a type of forward exchange contract, consisted of the calculation of the differential between the predetermined NDF rate and the realized spot exchange rate in a specific currency (usually the U.S. dollar), without the delivery of both currencies at maturity. The realized spot exchange rate is usually used as a spot rate before the deal's maturity (for won/dollar NDF contracts, the exchange rate on the day before the maturity date). Compared to typical forward exchange contracts, NDF contracts have lower settlement risks and allow offshore market transactions of relatively "non-internationalized" currencies.

The reason we use the NDF exchange rates in the analysis of forward market efficiency and the effect of liberalization in this section is that NDF rate is only consistent forward rate before and after the liberalization. Furthermore, the NDF rates are still expected to have significant information on the movement of domestic exchange rates. Therefore, it is reasonable that we consider the NDF rates as a proxy of domestic forward rates.

2. Theoretical Background

In an efficient market, the asset market operates according to rational expectations and there is no systemic bias in the formation of expectations. As a result, there are no excess expected returns in the asset market. The assumption of rational expectations implies that investors will take into account all available information when they engage in trade. Therefore, the price of an asset should fully reflect all available information that could influence the future expectation. In the foreign exchange market, the rate that reflects this expectation could be the forward exchange rate. If the market is efficient, both the spot and forward exchange rates fully reflect all available information and rational economic decisions. In this sense, if rational expectation is a feature of the foreign exchange market, then the forward rate should reflect all information that affects investors' expectation in a way that the mean of their expectation distribution is reflected in the forward exchange rate. With risk-neutral agents, no transaction cost and competitive market assumptions, the foreign exchange market will be efficient in the sense that the current forward rate is equal to the expected value of spot rate at the maturity date of the contract.

In the foreign exchange market, empirically showing that the forward exchange rate is an unbiased predictor of the spot exchange rate is closely related with testing the market's efficiency. This is explained as the following:

(1) $$f_{t,k} = E(S_{t+k})$$

$f_{t,k}$ is the log of the forward exchange rate[1] at period t for period $t+k$, and S_{t+k} indicates the spot exchange rate at the period of $t+k$. Equation (1) states that if the forward exchange rate is an unbiased predictor of the spot exchange rate, excess expected returns would not exist in the foreign exchange market. Assuming that rational expectations hold, we can define equation (1) as follows:

(2) $$E(S_{t+k}) = f_t + e_{t+k}$$

In equation (2), e is a white noise process. Equation (2) states that there are no systematic errors, based on rational expectations. Usually, equation (2), or the extent that the forward exchange rate predicts the spot exchange rate, is tested by the following regressive analysis:

(3) $$S_{t+k} - S_t = a + b(f_t - S_t) + e_{t+k}$$ [2]

For the forward exchange rate to be an unbiased predictor, the null hypothesis $a=0$ and $b=1$ should be satisfied. The argument is that if the foreign exchange market is efficient, the difference between the future spot rate and the current forward rate consists of a genuine error term that is independent of the current information set.

However, for the major international currencies under free floating exchange rate regime, regression analysis of equation (3) results in a b value that is not equal to one

[1] The reason that log values were used instead of level time series was to avoid Siegel's Paradox, which can arise due to Jensen's Inequality.

[2] Analysis using log difference was used to resolve the non-stationarity of the error term when the forward exchange and the spot exchange are *I (1)*.

(Bilson 1981, Fama 1984 and others).[3] Therefore, a bias exists between the forward exchange and the spot exchange, showing that most forward exchange rates fail as unbiased predictors.

In addition, the value of b was found to be negative among most developed countries. Froot (1990) found that the major currencies had an average estimated b value of -0.88. Therefore, profits can be made if one takes a position opposite the direction predicted by the forward exchange. This is called the forward premium puzzle. If we assume that rational expectations hold, this can be interpreted in two ways. First, it can be thought of as a risk premium or as an expected forecasting error. Second, it can be interpreted as the result of irrationality from the market's failure to combine the forward exchange with the systematic elements of the spot exchange.

In order to explain the forward premium puzzle, we need to decompose the b in order to explain the two different biases that occur under the assumption of rational expectations.

From the predictions of this sample, we can define:

(4) $$p\lim\left(\hat{b}\right) = b = \frac{Cov\left(f_t - S_t, S_{t+k} - S_t\right)}{Var\left(f_t - S_t\right)}$$

Here, Cov indicates covariance and Var indicates variance. If we assume that rational expectations hold, $Cov\left(f_t - S_t, S_{t+k} - S_t\right)$ can be defined as follows:

(5) $$Cov\left(f_t - S_t, S_{t+k} - S_t\right) = Cov\left(f_t - S_{t,} E\left(S_{t+k}\right) - S_t\right)$$

[3] Engel (1995) and Lewis (1994) explain in detail the results of existing studies.

First, if we assume that the risk premium is the only factor causing bias in the foreign exchange market, we can define the risk premium as:

$$(6) \qquad RP_t = f_t - E(S_{t+k})$$

where RP indicates the risk premium in the foreign exchange market. If market participants are risk-neutral and the market is efficient, the risk premium will have a value of zero. However, if market participants are risk-averse and the forward exchange rate is higher than the expected spot rate, players in the market will try to find compensation for their risk by increasing the future spot exchange to include the risk premium in the forward exchange price. Therefore, a systematic bias can exist in the values of the future exchange and expected spot exchange. If we try to explain the bias between the expected exchange rate and the forward exchange with only the risk premium, the theoretical bias between the spot exchange and forward exchange rates is defined as follows:

$$(7) \qquad E(S_{t+k}) - S_t = f_t - S_t - RP_t$$

If we rearrange the relation between equations (5) and (7), we arrive at:

$$(8) \qquad \begin{aligned} &Cov(f_t - S_t, E(S_{t+k}) - S_t) = Var(f_t - S_t) - Cov(f_t - S_t, RP_t) \\ &= Var(f_t - S_t) - Cov((E(S_{t+k}) - S_t, RP_t) - Var(RP_t) \end{aligned}$$

By decomposing b, we find:

(9) $\hat{b} = 1 - b_{rp}$, where $b_{rp} = \dfrac{Cov(E(S_{t+k}) - S_t, RP_t) + Var(RP_t)}{Var(f_t - S_t)}$

From equation (9), if we recognize the existence of a risk premium, there is no need for b to equal to one, depending on the presence of a risk premium. Moreover, the risk premium does not have to be a constant one. If a time-varying risk premium exists, the forward market bias may be different for each time period. Meanwhile, for b to be negative, which is a common case in the currencies of most developed countries, the two following conditions must hold (see Fama, 1984):

(10) $Cov(E(S_{t+k}) - S_t, RP_t) < 0$ and $Var(RP_t) > Var(E(S_{t+k}) - S_t)$

On the other hand, the finite sample bias provides another avenue for explaining expected forecast errors. In this case, the following decomposition can occur:

(11) $\hat{b} = 1 - \hat{b}_{rp} - \hat{b}_{fe}$

In equation (11), $\hat{b}_{fe}$ is a sample bias and has the following relation:

(12) $\hat{b}_{fe} = \dfrac{\hat{Cov}(f_t - S_t, E(S_{t+k}) - S_t)}{\hat{Var}(f_t - S_t)}$

In a limited probability distribution, $\hat{b}_{fe}$ can be seen as the deviation from the true value of b that arises in a given finite sample period. Therefore, the estimated $\hat{b}$ may not correspond to the true value b. However, as sample size grows larger, such sample bias is reduced and eventually approaches zero, such that $p\lim\left(\hat{b}_{fe}\right) = 0$.

Why does such sample bias arise in the finite sample period?[4] Let us assume that a regime shift is expected in the process of spot exchange rates, S_t. Although market participants react efficiently to the information of the coming regime shift, that information will be reflected gradually. Therefore, the covariance of $f_t - S_t$ and $E(S_{t+k}) - S_t$ may have a positive value for a given period of time and the value of $\hat{b}_{fe}$ may also be positive. Such sample bias will gradually disappear after the regime shift and this is commonly called "learning". On the other hand, let us assume that there are expectations of a regime shift, but actually the shift does not occur after a given period of time. Also in this case, the covariance of $f_t - S_t$ and $E(S_{t+k}) - S_t$ over a certain period of time may be positive. This is called the "peso problem". Because the effects of learning and the peso problem seem similar, these two cases are called the "generalized peso problem".

Under the assumption that bias in the forward exchange exists under rational expectations, the next chapter looks at the possibility of a time-varying risk premium as well as the peso problem between the offshore NDF exchange rate and the domestic forward exchange, in order to examine the efficiency of the domestic foreign exchange market. Moreover, focused on the effect of foreign exchange market liberalization, we will look closely at the structural changes in the foreign exchange market.

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[4] See Lewis (1995) for details on sample bias.

3. Ex Post Profit of NDF Rates

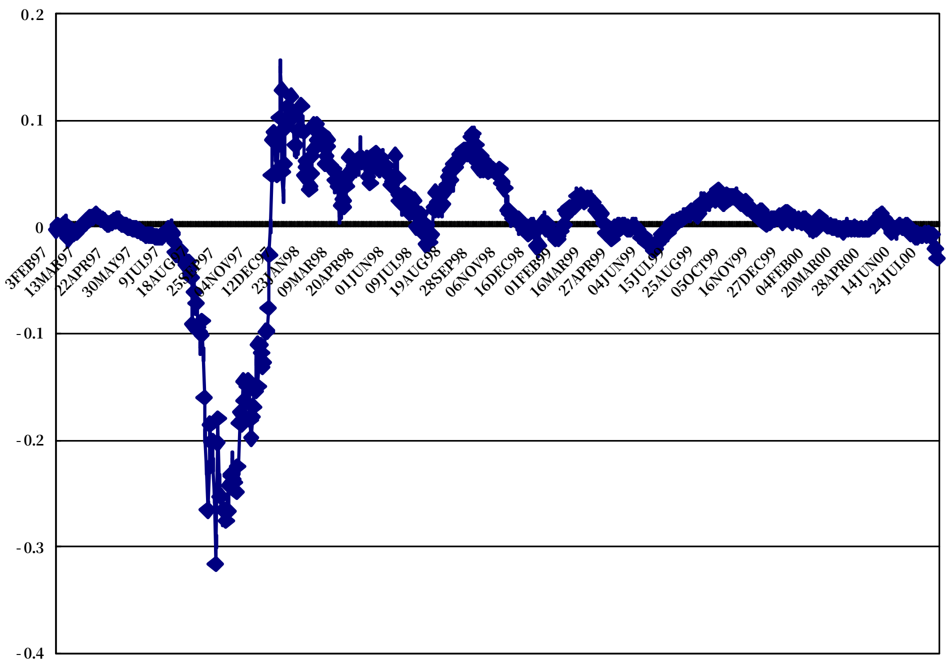
It is intriguing to investigate whether the NDF rates have ex post expected profit over the last three years so as to examine their predictability of future spot rates. This section examines the ex post excess expected profit in the domestic foreign exchange market using the offshore NDF exchange rates.

Figure IV-1 shows ex post excess profits (or losses) of the offshore three-month NDF rates. For the three-month NDF, $f_{t,k} - S_{t+k}$, or ex post excess profits seem to be very small before the financial crisis began in October 1997. It is mainly due to the exchange rate rigidity during the market average exchange regime. However, the values were continually and steeply negative from October 1997 to March 1998. This shows that from October 1997 to March 1998, during the early stage of the crisis, sellers of NDF contracts continually saw exchange differential losses from NDF transactions. Considering the severe impact of the currency crisis and highly erratic exchange rate movements during this period, forecasting spot rates seemed difficult. Therefore, the pressure to depreciate was so great that the realized spot rate was higher than the pre-determined NDF rates.

However, after April 1998, the won/dollar rates stabilized and ex post expected profits on the NDF rates have fluctuated between positive and negative. Especially since April 1999, the fluctuation of ex post expected profits has reduced, which means not only that the foreign exchange market was stabilized, but also that the foreign exchange market liberalization has indeed changed the market structure. In April 1999 domestic foreign exchange banks were allowed to participate in the offshore NDF forward market, which expanded the onshore market and diversified the market participants.

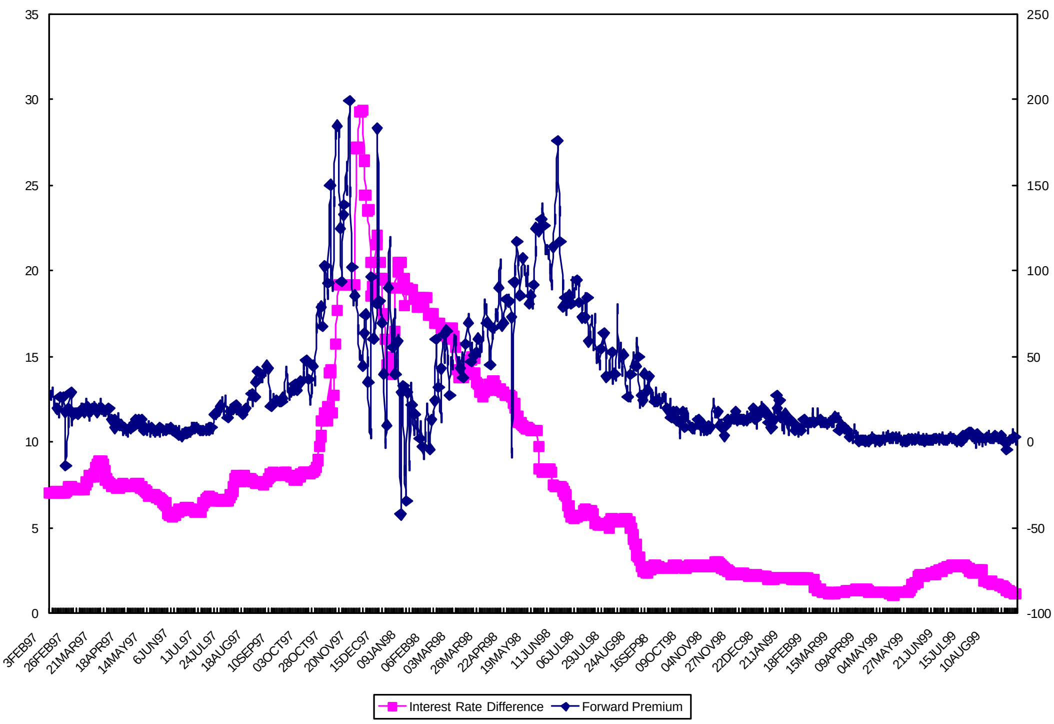
In general, such continued gains and losses on ex post expected profits of NDF transactions during a finite sample period show that the NDF exchange rate is not an ideal predictor of the domestic won exchange rate. This finding agrees with a recent study by Hae-shik Park and Chi-young Song (1999).

<Figure IV-1> Ex Post NDF Excess Profits (or Losses)



The reason for inaccuracy of the NDF to forecast the future spot rate mainly comes from the determining mechanism of the NDF rates. If we examine the fluctuations of the three-month NDF exchange rate's forward premium and the domestic and foreign interest rate differentials, we can see that the movements of these variables were very similar, except during the early phase of the financial crisis (see Figure IV-2). This suggests that the determining mechanism of the NDF exchange rate's forward premium offsets the profit from the differential between domestic and foreign interest rates, excluding times of extreme economic shock as witnessed during the financial crisis. In a situation where the domestic forward market is not developed, the determination of forward exchange prices by domestic-foreign interest rate differentials is unavoidable because there is no benchmark for forward prices. Therefore, unless the difference between domestic and foreign interests was realized, there would not be that many changes in the NDF rates.

<Figure IV-2> Domestic-Foreign Interest Rate Differentials and Forward Premium



4. Liquidity

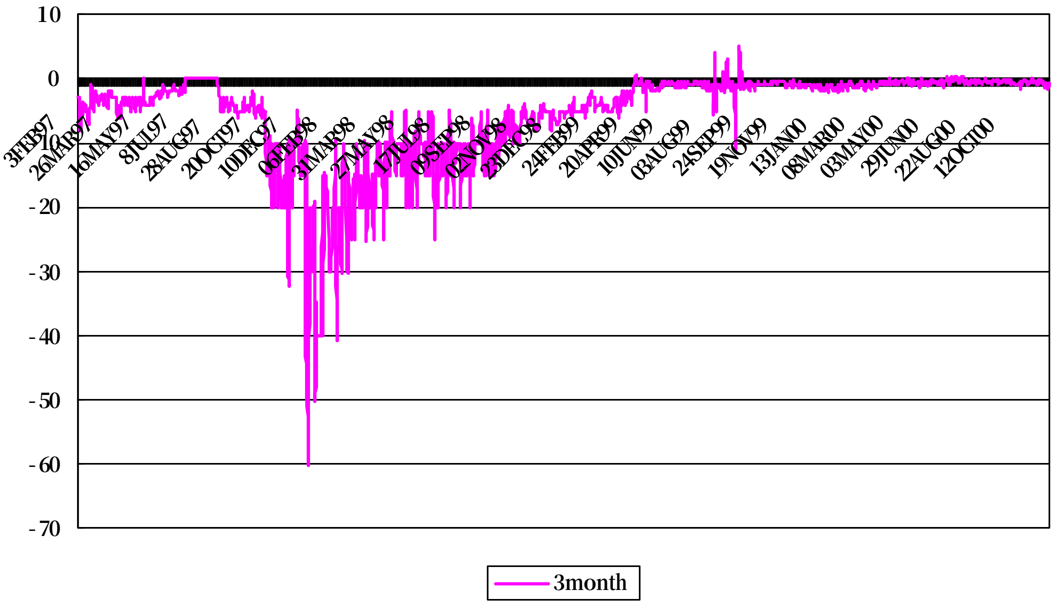
To assess the liquidity condition in NDF market, we examine the difference between bid prices and ask prices, since there is no available data on the trade volume of NDF transactions. If the market liquidity increases, then the difference between bid prices and ask prices would decrease. <Table IV-1> reports the average differences of bid/ask prices for three different periods. The first period represents the time before the financial crisis, from February 2, 1997 to September 30, 1997. The second period, defined as the crisis period, starts from October 1, 1997 and ends on March 30, 1999. The third period covers from April 1, 1999, when the first measure of foreign exchange market liberalization was implemented, to November 27, 2000.

When we compare the bid/ask differences between the first and third periods, the magnitude reduced by one fourth. This implies that the liquidity in NDF market has increased significantly. It seems that the first phase of liberalization has substantially influenced the market participants, since domestic foreign exchange banks were allowed to enter the offshore NDF forward market after the first liberalization in April 1999.

<Table IV-1> Average Bid/Ask Spreads

	1-month NDF	2-month NDF	3-month NDF	6-month NDF
Period 1	-4.33	-3.50	-3.47	-3.64
Period 2	-9.91	-11.89	-18.30	-14.88
Period 3	-1.11	-0.85	-0.88	-1.45

<Figure IV-3> NDF Bid/Ask Spreads



5. Foreign Exchange Market Liberalization and Market Efficiency

To test the efficiency of the domestic foreign exchange market by using the NDF exchange rates, we first test the unit roots of each variable, the results of which are in <Table IV-2>. <Table IV-2> shows the results of the unit root analysis using the Dickey-Fuller Test and the Phillips-Perron Test. In the case of level variables, we find both variables, spot and NDF exchange rates, have unit roots. However, unit roots did not exist for forward exchange premiums, thus showing that they had a stable process. Meanwhile, unit roots existed for most spot exchange differentials except for the one-month contract.

<Table IV-2> Unit Root Test

Variables		Dickey-Fuller	Phillips-Perron
Level			
	Spot rate	-1.863	-1.894
	1-month NDF	-1.823	-1.864
	2-month NDF	-1.927	-2.152
	3-month NDF	-1.815	-1.828
	6-month NDF	-1.769	-1.758
Difference between ex post future spot rate and spot rate			
	1-month (S_{t+K}-S_t)	-3.66*	-4.137*
	2-month (S_{t+K}-S_t)	-2.276	-2.455
	3-month (S_{t+K}-S_t)	-1.897	-2.079
	6-month (S_{t+K}-S_t)	-1.494	-1.776
Forward Premium			
	1-month	-4.072*	-7.356*
	2-month	-5.827*	-19.064*
	3-month	-2.960**	-4.064*
	6-month	-2.415	-3.05**

Note: 1. All values are log values.
2. Predictions from the Dickey-Fuller and Phillips-Perron Tests were made in consideration of the trend (t) and intercept.
3. ***(**)** indicates the rejection of the null hypothesis of unit root existence at a 1% (5%) statistical critical value.

To explore the long-run relationship between the domestic spot exchange and the NDF future exchange, we use the Johansen Co-integration Test. According to the test results, NDF rates, except for the two-month NDF rate, and spot exchange rates are co-integrated with at most one co-integration vector. This shows that the NDF bias can continue in the short run but that a given relationship will hold in the long run, which indirectly proves the efficiency of the domestic foreign exchange market.

<Table IV-3> Co-integration Test

	At most one co-integration vector exists	5% Critical value
1-month NDF and Spot	4.41	3.76
2-month NDF and Spot	3.63	3.76
3-month NDF and Spot	4.16	3.76
6-month NDF and Spot	3.95	3.76

5.1 Simple OLS Estimation

To test the efficiency between the domestic spot exchange rate and the offshore NDF rate, we use Ordinary Least Square (OLS) estimation to perform a regression analysis on the relationship described by equation (3).

(3) $$S_{t+k} - S_t = a + b(f_t - S_t) + e_{t+k}$$

The OLS estimation shows that the NDF exchange rate is not an unbiased predictor of the future spot exchange rate. The estimated value of b is greater than one (except for the case of one-month NDF), and it is statistically significant. The results of the Wald

Test also reject the null hypothesis of $a = 0$ and $b = 1$.[5] The estimation results are reported in Table 4.

<Table IV-4> Simple OLS Estimation

Independent Variables	a	b	Wald Test
1-Month	0.006 (6.1)	-2.71 (18.41)	53.2
2-Month	-0.0003 (-2.09)	1.71 (12.81)	75.2
3-Month	-0.0013 (-5.17)	2.75 (14.58)	28.8
6-Month	0.0057 (1.37)	0.650 (3.51)	6.93

Note: The sample period of the time series is from February 3, 1997 to November 3, 1999. A daily time series was used and regression analysis was performed on the differential between the forward exchange premium and the spot exchange.

The results of estimation in <Table IV-4> are first, based on the rational expectations hypothesis: if we assume that the risk premium or the peso problem does not exist, this means that the market is not rational. In other words, the NDF forward exchange does not properly predict market information.

Second, as shown in Table 4, the value of b is positive, which is in contrast with the negative b values of the major currencies under a free floating exchange rate

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[5] Wald Test results show the F-statistics of $W = (Rb - r)'\left[RVar(b)R'\right]^{-1}(Rb - r)$ under the null hypothesis of $a = 0, b = 1$.

regime. The positive value of b indicates that, assuming the interest parity holds, a rise in the domestic interest will cause the forward exchange rate as well as the spot exchange rate to rise. This explains the soaring won/dollar exchange rate immediately after the outbreak of the crisis, as well as the exchange rate's fall after a reduction of the domestic interest rate in the second half of 1998, which is shown by the regression analysis between the offshore NDF exchange rate and the domestic spot rate. Moreover, it can be found that the forward premium puzzle does not exist in the foreign exchange market. It is though that b has positive values because the sample period included times when the system has strong aspects of a managed floating or fixed exchange rate regime. Flood and Rose (1994) argued that positive b values are common for most of EMS, which has changed its exchange rate system from a floating to a fixed regime, currencies in equation (3).

This suggests that the covariance part of estimate b can be negative under a floating exchange regime, whereas b can be negative under a managed or fixed exchange regime (see equation (4)):

$$(4) \qquad p\lim\left(\hat{b}\right) = b = \frac{Cov\left(f_t - S_t, S_{t+k} - S_t\right)}{Var\left(f_t - S_t\right)}$$

Third, the value of b was estimated to be greater than one, which is a very rare occurrence. Lewis (1995) argue that during an EMS crisis, EMS member countries have b values greater than one if the system is collapsing. Therefore, the high b value arising in the regression analysis of the NDF and domestic exchange rates shows that the system was breaking down from the financial crisis.

5.2 Time-Varying Risk Premium

Based on the simple OLS estimation above, it can be concluded that the foreign exchange market in Korea is not efficient. However, let us assume that rational expectations hold and the bias of b can be explained by the risk premium as in equation (7). In this case, the estimated value of b need not equal to one, and the market is efficient, following the changes in the risk premium. In addition, if we assume that the risk premium is not simply a constant but varies for each period, that is, time-varying, we can test the market's efficiency using the ARCH-in-Mean model of Engle, Lilien and Robins (1987).

(13) $$S_{t+k} - S_t = a + b_1 (f_t - S_t) + b_2 r_t + e_{t+1}$$

where, $r_t^2 = d + j e_{t-1}^2$

r_t in equation (13) is defined as the time-varying risk premium composed of functions of the past expected error. A significant probability value of j in equation (13) determines if the forward exchange bias can be explained by the past conditional variance. Significant probability values of d and j indicate that a time-varying risk premium exists for forward market bias. If d is significant while j is not, a constant risk premium exists. Table 5 shows the results of ARCH-in Mean Regression for equation (13).

<Table IV-5> ARCH-in-Mean Estimation Results

	a	b_1	b_2	d	j
1-Month NDF	0.0003 (2.25)	0.731 (24.43)	-0.198 (-11.10)	0.0006 (12.28)	1.16 (12.94)
2-Month NDF	0.0009 (0.007)	1.79 (0.79)	-0.075 (-0.01)	0.00006 (0.004)	1.16 (0.06)
3-Month NDF	0.002 (11.53)	0.562 (27.4)	-0.283 (-8.6)	0.0003 (8.04)	1.115 (11.01)
6-Month NDF	-0.005 (-31.1)	0.95 (41.35)	-0.179 (-9.85)	0.0005 (5.83)	1.06 (42.72)

Note: Figures in parentheses indicate *t*-value.

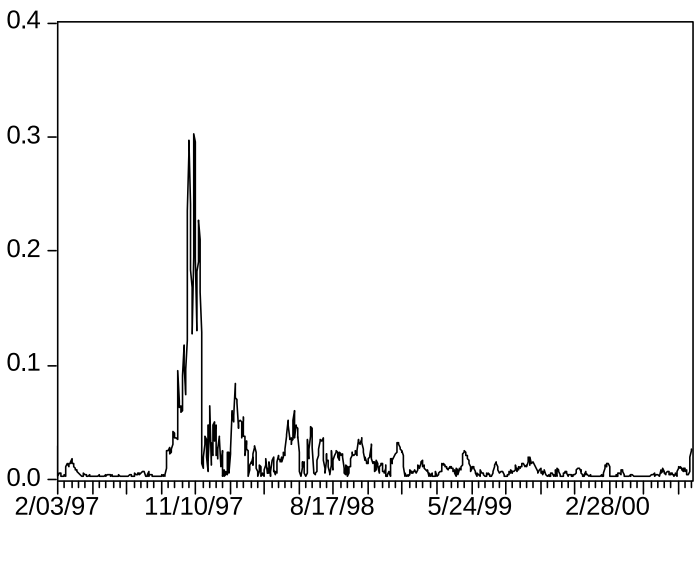
The ARCH-in-Mean estimates show that a time-varying risk premium exists in the relations between the domestic forward exchange and the offshore NDF exchange rate. Most of the variables explaining the time-varying component, including b_2, d and j, are statistically significant with an exception of two-month NDF case. Therefore, the domestic foreign exchange market can be seen as efficient under the rational expectations hypothesis with the time-varying risk premium. This result agrees with the co-integration result in the previous section.

b_2 is shown to have negative values, meaning that the risk premium for buying the NDF forward exchange is positive (except for two-month NDF rates). This shows that won-denominated financial assets were riskier than dollar-denominated assets.

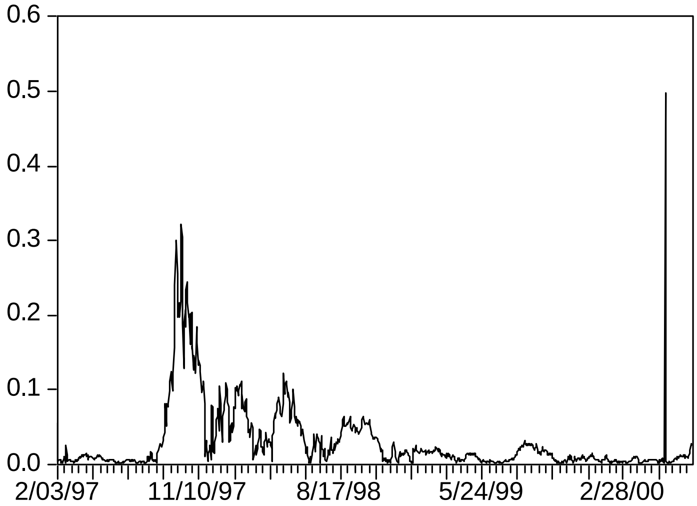
After estimating the ARCH-in-Mean model, we graph the corresponding time-varying risk premiums, r_t in equation (13). These graphs show that the risk premium of domestic currencies soared after November 1997, when the crisis situation was rapidly worsening, and stabilized in the second half of 1998. In addition, risk premiums were mostly low without much fluctuation before the crisis, which can be seen as the exchange rate fixing effect characteristic of the market average exchange rate system. However, after the adoption of the free floating exchange rate system, the risk premium rapidly increased. In addition, the differences between the risk premiums for different periods clearly show the effect of an exchange rate regime shift on the risk premiums.

In terms of the time-varying risk premium, we can see the difference before and after the liberalization. If we compare the sizes of time-varying risk premium at different times, the time-varying risk premium in Period 3 (after the liberalization) is bigger than that of Period 1 (before the liberalization; Period 2, the crisis period is excluded). Even though the size of the time-varying risk premium has diminished during Period 3, as the domestic economy has stabilized, the volatility of risk premium is expected to have increased by responding to future economic shocks.

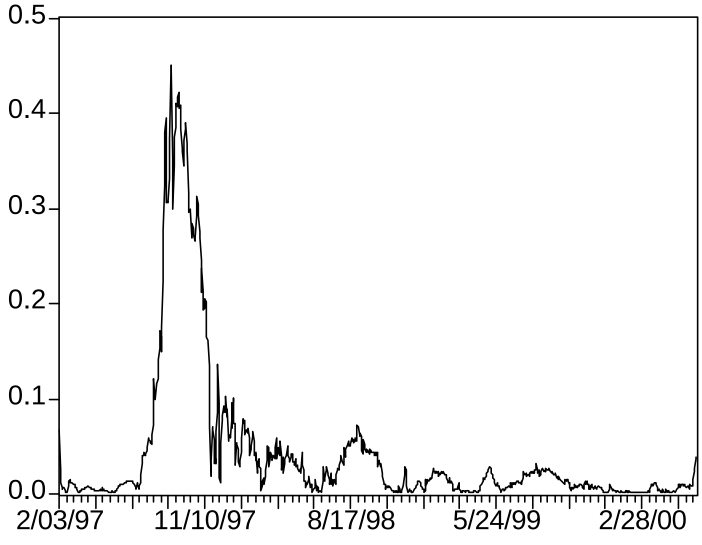
<Figure IV-4> 1-Month NDF Time-Varying Risk Premium



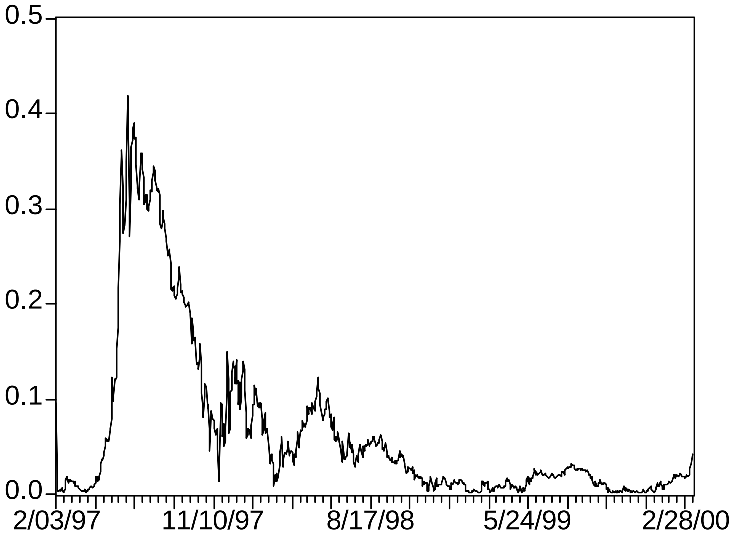
<Figure IV-5> 2-Month NDF Time-Varying Risk Premium



<Figure IV-6> 3-Month NDF Time-Varying Risk Premium



<Figure IV-7> 6-Month NDF Time-Varying Risk Premium



To examine the changes of time-varying components, we estimate equation (13) by three different periods. The estimation results show that the time-varying coefficients $\boldsymbol{b}_2$ are statistically significant in Periods 2 and 3. By comparing the values of $\boldsymbol{b}_2$ between Period 1 (pre-liberalization) and Period 2 (post-liberalization), it is fair to say that the time-varying coefficients are important factors in explaining the exchange movement, since the values of $\boldsymbol{b}_2$ in Period 1 are not statistically significant in the cases of one-month and three-month NDF rates. In addition, it is interesting that the coefficients of $\boldsymbol{b}_2$ in Period 2 show positive values. This reflects that the won/dollar rate has greater pressure to appreciate, and, therefore, market participants consider the won-denominated financial assets more attractive.

<Table IV-6> ARCH-in-Mean Estimation by Period

	Coefficients	Period 1	Period 2	Period 3
1-month NDF	a	0.001 (2.09)	-0.11 (-11.47)	0.008 (2.41)
	b_1	0.696 (10.96)	0.942 (9.63)	0.577 (3.09)
	b_2	-0.004 (-0.036)	0.161 (2.49)	-0.198 (-2.25)
	d	0.00016 (1.9)	0.0003 (5.180	0.00034 (4.69)
	j	1.21 (2.19)	1.07 (6.87)	1.003 (4.92)
2-month NDF	a	0.0084 (19.7)	0.002 (24.1)	0.002 (25.0)
	b_1	0.481 (12.33)	2.74 (5.3)	0.038 (8.14)
	b_2	-0.478 (2.46)	0.236 (5.48)	-0.12 (7.34)
	d	0.00001 (2.41)	0.0001 (5.41)	0.00004 (7.37)
	j	0.95 (2.56)	1.01 (5.87)	1.2 (13.36)
3-month NDF	a	0.003 (12.23)	-0.017 (-14.04)	0.0015 (5.00)
	b_1	0.405 (7.51)	0.82 (13.43)	0.64 (2.41)
	b_2	-0.275 (1.41)	0.044 (1.05)	-0.308 (-3.89)
	d	0.00006 (4.32)	0.00001 (12.46)	0.00002 (4.91)
	j	1.21 (23.64)	1.06 (7.70)	1.042 (4.79)
6-month NDF	a	0.003 (4.15)	-0.006 (-9.12)	-0.004 (-9.29)
	b_1	0.466 (6.30)	0.246 (10.41)	-0.014 (-0.7)
	b_2	0.497 (6.67)	-0.167 (-8.09)	-0.32 (-3.4)
	d	0.00001 (1.71)	0.00005 (2.58)	0.00004 (3.69)
	j	1.25 (3.69)	1.204 (6.58)	1.04 (4.09)

5.3 Structural Changes and the Peso Problem

The previous section showed that a rise in the won exchange rate's risk premium caused overshooting in the domestic exchange rate. This sub-section examines whether the peso problem exists in the relationship between the domestic won exchange rate and the offshore NDF exchange rate. The sample period from February 3, 1997 to November 27, 2000 is divided into three periods and we estimate the changes of b in equation (3).

As mentioned earlier, if a regime shift was expected before the crisis, this would have caused the offshore NDF exchange rate and in turn the forward premium to rise before the crisis. This is illustrated in Figure 1. However, with a regime shift from a market average exchange rate regime to a free floating regime, the effects of the shift will diminish over time. Therefore, the value of b will fall over time. Table 5 shows the change in the values of b during the sample period in equation (3) through a regression analysis of the changes in 1-, 2-, 3- and 6-month NDF forward exchange premiums and the spot exchange rates for each period. The reason why we first test the structural changes by utilizing equation (3) is that we want to isolate the structural changes from the effect of time-varying components.

<Table IV-7> OLS Analysis of UIP by Period

	Variable	Period 1 (Feb. 3, 1997 to Sep. 30, 1997)	Period 2 (Oct. 1, 1997 to Mar. 30, 1998)	Period 3 (Since Apr. 1, 1998)
1-Month NDF	α	-0.001 (-2.76)	-0.015 (-5.8)	-0.009 (-2.44)
	β	0.683 (4.56)	-3.386 (-12.42)	2.5 (3.82)
2-Month NDF	α	0.001 (0.57)	-0.03 (-7.58)	-0.0019 (-3.63)
	β	1.104 (6.77)	4.28 (14.27)	0.006 (1.53)
3-Month NDF	α	0.003 (1.58)	-0.04 (-6.76)	-0.005 (-7.57)
	β	1.083 (3.76)	3.38 (11.01)	1.41 (1.89)
6-Month NDF	α	0.007 (1.37)	-0.092 (-14.79)	-0.012 (-12.9)
	β	0.608 (2.83)	2.07 (12.01)	0.89 (3.33)

Note: Figures in parentheses represent t-statistic value.

As the test results tell us, the estimated value of b varies for each period. The coefficient b has positive values before the crisis, higher positive values as the crisis worsens (greater than one) and after April 1999, reduces to the point of approaching one, although not all b estimates are statistically significant. This means that the regime shift has influenced the exchange rate after the crisis occurred. The regime shift is also confirmed when we include the time-varying component by examining <Table VI-6>, since b_1 reduced noticeably between Period 2 and Period 3. In order to prove the structural break in the domestic foreign exchange market, the results of Chow's breakpoint test are reported in <Table IV-8>. The null hypothesis is that there is no structural break in those three different periods. *F*-statisticsm and log likelihood ratio tests (log likelihood test is estimated by Maximum Likelihood Estimation of equation (3) by period) show that we can reject the null hypothesis.

<Table IV-8> Chow Test

(?)	Test statistics
F-statistics	24.08
Log likelihood	94.58

Combining the structural changes (or regime shift) during the sample period with the changing value of b, we conclude that the peso problem can explain the bias of the forward exchange during the sample period, as we defined the peso problem in equation (11).

On the other hand, there is no significant difference in Periods 1 and 3, based on estimation results of equation (3). The liberalization and the exchange rate regime shift are expected to change the structure of the foreign exchange market. However, the b coefficients in Period 3 still have positive value as in Period 1. This reflects that the domestic foreign exchange market in Period 3 is not much different from that in Period 1. Furthermore, the positive b values in Period 3 indicate that even though Korea adopted a free floating exchange regime, the exchange rate regime is more likely to be classified as managed floating regime, as mentioned earlier.

V. Summary and Policy Implications

After the East Asia crises, the Korean government has actively taken various liberalization measures to make the economy resilient to various domestic and external shocks. As part of those measures, this study concentrates on the liberalization of the foreign exchange market. We provide general descriptive information about the structure and characteristics of the foreign exchange market in Korea. Also, we empirically analyze how the foreign exchange market liberalization affects the market based on market microstructure theory (in chapter III) and usual rational expectation hypothesis framework (in chapter IV).

Our empirical findings in chapter III are as follows. First, large price and volume movements of private information generate persistent responses before and after the liberalization even if the degree of persistence after the liberalization is much smaller than before the liberalization. The results lead us to conclude that the market becomes relatively more efficient after the liberalization, under the framework often going by the name of noisy trading model. That is to say, informed traders may earn much more at the expense of less informed traders, but the first can enjoy high profits in a relatively short duration after the liberalization.

Second, the public information shocks do not affect the volatility of the exchange rate in the short run, but the effects do not dampen for a longer term in both periods. The same is true for volatility, even though the result is barely statistically significant.

Third, the volume shocks or disparate belief shocks are major sources of price deviation from the average exchange rate and persistence in the volatility in before and after the liberalization. Therefore, the trading volume itself generates “excessive volatility” in the market. We interpret the result as supportive of the noisy trading model, though our empirical setup does not directly test the model itself. The fact that the magnitude of the total deviations from the baseline becomes much smaller after the liberalization drives us to lean toward a more positive attitude for the liberalization.

Empirical results focusing on the forward markets in chapter IV can be summarized as follows. First, we look at the changes in ex post profits of NDF rates during the sample period. It allows us to find out whether the NDF rates are operating efficiently, and whether the market is expanded and diversified in terms of market operation. We note that ex post profits of the NDF rates were very small before the crisis and negative during the crisis period. However, recently the ex post profit is fluctuating, showing both positive and negative values. It is believed that this comes from the liberalization measure that allowed domestic banks to participate in the offshore NDF market as of April 1999.

Second, we assess the market liquidity over three periods and find that the liberalization has indeed increased the market liquidity. To examine the liquidity condition, the difference between bid-price and ask-price is carefully measured, since there is no available data on the trade volume of the NDF transaction. Due to the liberalization, the liquidity in the forward exchange market is expected to increase as more participants enter the market. The liquidity has increased as the bid/ask difference reduced by about four times between Periods 1 and 3.

We recognize that the forward premium puzzle exists in the domestic foreign exchange market. Moreover, the value of b is positive and greater than one. This indicates that the influence of crisis still exists in the foreign exchange market. We also prove that the offshore NDF exchange rate is not an unbiased indicator, and that a bias exists between the offshore NDF forward exchange and the domestic spot exchange. In addition, a forward exchange bias clearly appears in the domestic foreign exchange market, indicated by the fact that it did not have a forward premium bias as seen in the major exchange rates in the free floating exchange rate system. Thus, while most forward exchange rates are known to have a downward bias, an upward bias was observed domestically. This upward bias is thought to have been caused by the system collapse following the shock from the financial crisis. In addition, the upward bias implies that in Korea the interest rate equilibrium condition is satisfied at least in terms of direction. To make an analogy, the government’ s interest rate stabilization efforts after the crisis greatly helped the exchange rate's downward stabilization. Bias in the domestic foreign exchange market can be explained by confirming the existence of a risk premium or the peso problem. This means that the existing bias in domestic foreign exchange market can be understood as the risk premiums of forward exchange buyers and sellers or the expected excess profits (or losses) from expectations of a regime shift.

The empirical findings are so important for policy makers in implementing effective exchange and monetary policies in Korea.

First, the possibility of excessive volatility caused by noise or bandwagon holds a policy implication for the exchange rate system in Korea. After the East Asian crises, the choice of exchange rate regime in developing countries received special attention from the academia and policy circles. An intermediate regime between the two polar solutions, i.e. fixed and floating flexible exchange rate regimes was not easy to keep due to the deep economic integration of developing countries. Shifting to more extreme choices between free floating and credible institutional arrangement has been recommended to many developing countries. Crisis countries, including Korea, have adopted fully flexible exchange rate regimes after the crises. Countries that chose a more flexible exchange regime are concerned that the choice lies in volatility of the short-term exchange rates and misalignment in mid- or long-term exchange rates. For developing countries with weak financial markets, volatility of exchange rates raises their vulnerability. Furthermore, it is a general consensus that the exchange rate volatility does not always derive from economic fundamentals. Rather, both the literature and new empirical evidences show that exchange rate regimes differ primarily by the noisiness of the exchange rate.[1]

It is easier to infer policy implications by connecting our empirical findings with the argument by Jeanne and Rose (1999). They propose a theoretical noisy trading model and contend that exchange rate volatility affects the presence of noise traders. That is, noise traders create exchange rate volatility if they choose to enter the foreign exchange market. Our results show that the degree of excessive volatility in the market becomes weaker after the liberalization or adoption of a flexible exchange rate system. Are the empirical findings are not consistent with the model? The clues on the seeming contradiction can be reconciled with the fact that the absolute magnitude of the estimated conditional volatility decreases by more than ten times. As the volatility of the exchange rate decreases, the risk premium become smaller and the incentive for noise traders to participate in foreign exchange transactions shrinks. Is it possible for a government to choose an exchange rate regime that can lower exchange rate volatility or to design exchange rate policy that affects the composition of the foreign exchange market? Jeanne and Rose (1999) provide an optimistic answer for the question, such as adopting a target zone model. If the model (or a more sophisticated one) can be validated with empirics, one possible candidate of appropriate exchange rate system in Korea would be multilateral arrangements in the sense of minimizing exchange rate volatility via reducing noisy traders.

Second, the liberalization improves the efficiency of the NDF exchange market in terms of liquidity and market participants. This induces a more efficient domestic exchange market, since the offshore NDF rates certainly exert influence on the domestic spot rates.

[1] See Jeanne and Rose (1999), Farque and Redding (1999) and Hau (1998).

Some argue that the increasing depreciation pressure of won/dollar exchange rates after the crisis results from the upward pressure of the NDF rates. The NDF rates have at best become closely related with the domestic currency future rates. This implies that if we want a more efficient foreign exchange market, it is better to have more various participants in the market.

Direct intervention has been an effective method of stabilizing the exchange rates in Korea. However, the effect of direct intervention is expected to diminish, since the domestic capital market is more open and liberalized today. In line with this, the authorities should consider indirect intervention or operation through interest rate policy in order to minimize the fluctuation of the won/dollar exchange rate. In a small open economy with a floating exchange regime, the management of short-term volatility and long-term misalignment is the most important policy objective. However, what the adequate policy tools for this are still remains unclear. In general, increasing (decreasing) interest rates is frequently used to mitigate the depreciation (appreciation) pressure.

Based on the empirical findings in this paper, indirect intervention of the traditional interest rate policy may not be effective as much as the traditional theory expected. This is due to the risk premium in the determination of exchange rates. Traditional interest rate policy on exchange rate states that increasing domestic interest rates induce more capital inflows, and in turn the domestic exchange rates appreciate. However, this would happen only if interest rates and foreign exchange risk premiums were orthogonal. In other words, the exchange rate depreciates rather than appreciates in the case that the increasing interest rate influences the risk premium as a sign of weak economic conditions. According to empirical analysis in chapter IV, the changes of exchange rates depend on the interest rate differential as well as the risk premium. Since the forward rate and the realized expected spot rate are correlated positively, capital outflows occur and the domestic currency depreciates as the interest rate differential increases. As the time-varying risk premium is deemed an important factor in the foreign exchange market, it is better to understand the effect of risk components in determination of the exchange rates.

The development of domestic bond market is also another important economic objective for the Korean economy. An efficient and active bond market provides not only effective benchmark rates in the foreign exchange transactions, but also alternative financial assets to diversify risks. This results in a deeper and more efficient foreign exchange market. Concisely put, the development of foreign exchange market requires a more efficient domestic financial market in general.

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ISBN 89-322-1124-8
89-322-1088-8(세트)
값 5,000원
Price USD 5