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Why Central Banks Intervene?

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<요 약>

1960년대, 각국의 환율이 미국의 달러화에 연동(pegging)된 고정환율제도를 근간으로 하는 브레튼우즈(Bretton Woods)체제하에서 각국의 중앙은행은 환율을 일정한 범위 내로 유지하기 위한 정책수단으로 원환시장개입을 적극 활용하였다. 1973년 브레튼우즈체제하의 고정환율제도가 붕괴되고 변동환율제도가 채택된 이후에도 각국의 외환시장개입정책은 계속되었다. 1980년대에 레이건 행정부의 재정팽창정책과 미연방준비은행의 긴축통화정책으로 금리의 진속적인 상승과 미달러화의 큰폭의 절상이 이루어 졌다.

이에 국제무역의 위기를 우려한 미국, 독일, 프랑스, 영국, 일본 등 선진 5개국(Group-5, G5)은 1985년 9월 22일 미 달러화의 절하를 위해 외환시장에 공동으로 개입할 것을 주내용으로 한 플라자합의(Plaza Agreement)를 발표하였다. 그후에도 1987년 2월 23일 열린 루브르협정(Louvre Accord, G-6 Communique)에서 환율을 현수준으로 유지시키기 위한 목표환율대(Target zone)를 설정하고 외환시장개입을 통해 이를 유지하기로 합의한 바 있다. 이후의 구미각국은 환율의 관리를 위하여 국가가 공동으로 외환시장에 개입하곤 했다.

본 논문은 1987년 루브르협정 이후 미국, 독일 및 일본의 중앙은행의 외환시장 개입정책이 소기의 목적을 달성했는지의 여부를 규명해 보고자 한다. 즉, Federal Reserve, Bundesbank 및 Bank of Japan의 외환시장개입이 현물환율시장(spot market)엑서 각각의 변동성을 감소 시켰는지의 여부를 독일의 마르크화 및 일본의 엔화를 중심으로 규명해 보고자 한다. 1987년 루브르협정이후, 미국, 독일 및 일본의 중앙은행은 미국 달러화에 대한 마르크 및 엔화의 환율을 안정시키기 위해 꾸준히 외환시장에 개입해 왔다. 외환시장의 개입유형은 크게 태화외환시장개입(non-sterilized intervention)과 불태화외환시장개입(sterilized intervention)으로 구분할 수 있는데, 전자는 외환당국이 민간부문과 외화채권을 거래함으로써 본원통화의 크기가 변하는 개입형태를 의미하는 반면

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에 후자는 외환당국의 순외화자산의 크기변화가 본원통화의 변화를 초래하지 않는 경우이다. 즉, 불태화외환시장개입은 순외화자산의 증감이 순국내자산의 증감과 반비례해서 이루어지기 때문에 본원통화의 크기에는 변함이 없다. 외환시장개입이란 외환당국이 은행간 시장에서 민간시장 참가자들과 행하는 적극적인 외환거래를 의미한다. 반면, 넓은 의미에서의 외환시장개입에는 수동적외환시장개입이라고 불리는 고객거래가 포함된다. 후자의 거래는 국내통화 및 외화표시자산의 상대적 공급규모를 변화시킨다는 의미에서 전통적외환시장개입과 동일한 효과를 갖기 때문에 광의의 외환시장 개입으로 분류된다.

외환시장의 개입목적은 크게 세 가지로 분류할 수 있다.

첫째, 환율의 안정적 운영이다. 환율수준이 자유롭게 변화되는 변동환율제도하에서 환율의 지나친 변동으로 인한 실물경제로의 부정적인 영향을 최소화하기 위해서 환율의 지나친 변동으로 인한 실물경제로의 부정적인 영향을 최소화하기 위해서 환율의 안정을 정책 목표로 설정하는 경우와 고정환율제도하에서 환율을 일정수준으로 유지시키기 위해서 외환당국이 외환시장에 개입하는 경우가 여기에 해당된다고 볼 수 있다. 둘째, 환율수준의 균형수준으로의 조정이다. 이때 야기될 수 있는 문제점으로는 환율균형수준을 어떻게 정의, 추정할 것이냐 하는 점과 목표환율정책이 다른 정책목표와 상충될 수 있다는 점이다. 셋째, 외환당국이 공적외환보유액이나 구성을 변화시킬 목적으로 외환시장에 개입하는 경우이다. 이때의 외환시장개입은 현재의 환율수준이 개입으로 인하여 과도하게 이탈하는 문제가 발생하지 않을 것을 전제로 한다.

본고에서는 현물환율에 영향을 미치는 요소로 미국, 독일 및 일본의 중앙은행의 개입효과, 요일효과, 통화의 공급량(M1), 무역적자의 폭, 산업의 생산량, 생산가격지수(PPI), 소비자물가지수(CPI), 실업률, 옵션의 내재적 변동성등을 고려한다. 환율의 변동성을 추정하는 식은 GARCH 모델이 사용된다. 본 추정모델은 Dominguez(1993)의 확장이다. Dominguez (1993)의 논문은 GARCH 모델을 써서 미국, 독일 및 일본의 중앙은행의 시장개입효과를 분석했으나, 거시변수를 고려대상에서 제외시켰다. 본 논문은 위의 방법에 거시변수를 삽입하고 모델을 변형시켜서 더 확실한 시장개입효과와 거시변수효과를 밝혔다. 또한 옵션의 내제적 변동성을 구하는 과정에서 American option model을 사용하는 대신, Bourtha & Courtadon (1987)등이 밝힌 바와 같이 American style option이라 할지라도, European Model을 쓰면 더욱더 간편하고, 예측력도 American Model에 뒤지지 않음을 이용하여, European Model을 써서 내재적 변동성을 구한 다음 이것을 독립변수로 이용하였다. 본 모델의 추정 결과는 3국의 시장개입정책이 현물환율과 옵션의 내재적 변동성을 증가시켜서 Louvre 협정이후 각국은 시장개입의 목적을 달성하지 못한 것으로 나타났다.

Ⅰ. Introduction

After the abandonment of the Bretton Woods system, the exchange rates have displayed a high degree of time-conditional volatility. Since the excessive volatility often affected the economy, central banks began to intervene to support dollar in the foreign exchange market. Many study results, however, suggest that the intervention cna have an effect on the exchange rate but that its effect will last only temporarily if macroeconomic policies are left unchanged.[1] There, however, exists no general consensus regarding this issue.

The purpose of this study is to test how central bank jinterventions affected the volatilities of the DM and the YEN exchange rates during the post-Louvre period. Thus, we will examine whether the central bank interventions helped to stabilize "disorderly market" conditions. To do that, we will also use currency otions price model to calculate changes in the implied volatilities of the DM and the YEN exchange rates. These implied volatilities are likely to provide reasonable estimates of ex ante volatility based on current market-determined prices.

This estimate will be unbiased if we assume that the options market is efficient and that the option pricing model is correct. The paper extends previous research done by Dominguez(1993) and Bonser-Neal and Tanner(1995). The former examines the effects of central bank interventions on changes in the implied volatilities of foreign exchange rates. The latter examines the intervention effects on the levels of volailities of foreign exchange rates. Since asset prices are commonly believed to react sensitively to economic news, we include several macroeconomic variables in some of our regressions to control for volatility changes that might result from factors other than those central bank interventions.

The paper differs in several respects from Dominguez(1993). Bonser-Neal and Tanner(1995). First, the former does not include macroeconomic variables in the GARCH model. We, however, include them. Second. the latter uses the Barone-Adesi-Whaley(1987) model to find implied volatility. We. however. use the Garman-Kohlhagen model. Examining the effects of central bank interventions on the level and

1) See Greene (1983a).

on change of the exchange rate volatility, our research, in part, will improve the understanding jof the policy effects of the Federal Reserve, Bundesbank and Bank of Japen's foreign exchange markets.

Ⅱ. THE EFFECTS OF CENTRAL BANK INTERVENTIONS ON THE VOLATILITY OF EXCHANGE RATES

In the arena of foreign exchange markets, central banks often intervene to reduce day-to-day fluctuations in exchange rates. Whether a central bank intends to stabilize exchange rate movements over the short run, or to pursue longer run objectives such as defending a particular exchange rate, it often carries out its operations on a day-to-day basis. Intervention operations are often geared toward quieting disorderly markets, and a central bank must decide daily whether to intervene. In the early 1980s, however, economists began to question the effectiveness of intervention as an independent policy tool. This view was probably influenced by research in the late 1970s showing that exchange markets are efficient, requiring no risk premium to engage in cross-currency arbitrage, and that the exchange rate can and should be viewed as the relative price of domestic to foreign currency. It may also have been influenced by the large number of studes rejecting the empirical significance of intervention. Intervention operations aimed at decreasing the value of the domestic currency involve the official sale of the domestic currency in exchange for a foreign currency.

If the central bank sells domestic currency that was not previously in circulation, the intervention operation will expand the domestic money base. Likewise, an intervention operation aimed at increasing the value of the domestic currency involves buying the domestic currency in exchange for a foreign currency. If the central bank takes the domestic currency receipts out of circulation, the intervention operation will contract the comestic money base.

We consider two types of exchange interventions, one is sterilized intervention and the other is nonsterilized interventions. Any intervention operation that involves a change in the domestic monetary base is called a nonsterilized intervention operation.

Nonsterilized intervention operations are analogous to domestic open market operations, except that foreign rather than domestic assets are bought or sold. In monetary models of exchange rate determination, nonsterilized intervention will affect the exchange rate in proportion to the change in the relative supplies of domestic and foreign money, just as any other form of nonetary policy does. This case involves a change in the domestic monetary base.

Sterilized intervention is an intervention that is accompanid by an offsetting open-market operation that restores the domestic monetary base to its original size. Foreign exchange market intervention is any transaction or announcement by an official that is intended to affect the value of exchange rates. Central banks define intervention as any official sale or purchase of foreign assets against domestic assets in the foreign exchange markets. Intervention policy may be very important for economic agents because the volatility of the exchange rate reflects underlying economic conditions.

There are many empirical studies that examine the effects of the interventions and macroeconomic announcements on the level of exchange rates.[2] Until recently, however, there is no general consensus regarding these issues and advance in time series modeling and currency options theory have not been used in these contexts. The recent studies have begun to correct this shortcoming. This paper will add to their works.[3]

Ⅲ. DATA AND ESTIMATION MODEL

3. 1. DATA

a. Spot Exchange Rate Data

The exchange rate data used in the empirical tests are compiled from the Federal Reserve Bank of New York. Our data consist of daily closing bid prices of two major

2) For the intervention effects, see Edison.(1993), Dominguez and Frankel (1993a, 1993b), Klein and Rosengren (1991) and Obstfeld (1990). For the effects of macroeconomic announcem6ents, see Madura and Tucker (1992) Hogan, Melvinand Roberts (1991), Hardouvelis (1988).

3) See Dominguez (1993), Baillie and Humpage (1992), Almerkinders and Eijffinger (1992), Humpage and osterberg (1990), and bonser-Neal and Tanner (1995).

currencies:

Deutsche Mark(DM) and japanese Yen(YEN). We use 665 daily observations, from February 23, 1987 to December 31, 1989. The rates of change are calculated by taking the logarithmic differences between successive trading days.

b. Central Banks Intervention Data

Until recently, most central banks havr not routinely made daily intervention data available to the public. At the Versailles Summit in 1982, the Group of Seven (G-7) central banks agreed to share daily intervention data with each other as part of a multi-country study of intervention policy. The US Treasury has allowed the Board of Governors of the Federal Reserve System to make its daily intervention data publicly available with a minimum of a noe-year lag. The intervention data were provided to us by the Board of Governors of the Federal Reserve System. However, Bundesbank and Bank of Japan actual data are unavailable, we use reported data from the Wall Street Journal. And, since we want to examine the effects of the three central bank interventions on the volatilities of the DM and YEN exchange rates during the post-Louve Accord period, we use the data for the time period from February 23, 1987 to December 31, 1989. We use dummy variable. Table 3-1 shows total number of central bank intervention data during our sample period.

Table 3-1

Daily entral bank Intervention Data

Sample period: February 23, 1987-December 31, 1989, obs=665.

Central Banks	Against the $/DM	Against the $/YEN
Federal Reserve*	145	131
Bundesbank**	97	---
Bank of Japan***	---	114

* = Panel reports the number of days the Federal Reserve(actually) intervened in each currency. Source: Board of Governors. Federal Reserve.

** = Panel reports the number of days the Bundesbank intervened each exchange rate. The data show Wall Street Journal.

*** = Panel reports the number of days the Bank of Japan intervened in each exchange rate. The data show Wall Street Journal reports. Source: The Wall Street Journal.

c. Currency Options Data

The data utilized in this dissertation are based on daily transactions data from the PHLX for the time period from February 23, 1987 to December 31, 1989. Since the DM and the YEN are the most actively traded in the foreign currency option rrading market, we select their call options price data. The expiration months for these contracts are March, June, September and December. In addition, the exchange added contracts expiring in the nearest two months surrounding these quarter months. These are transactions on the spot exchange rate. Since these options are both written and traded on an organized exchange, they have standard contract sizes, standardmaturity dates, and predetermined exercese prices.[4] Our study sample is restricted to near at-the-money call options with 7 to 100 days to maturity. Near at-the-money options are used because they tend to be the most sensitive to changes in volatility, and hence the most informative about volatility.[5]

Since the PHLX data base does not provide data on interest rates, daily domestic and foreign interest data have been obtained from the Solomon Brothers Inc.[6] We use Euro-currency bid rates(deposit rates) and German and Japanese annualized interest rates. We use the data for maturities of 7 days, 1, and 3 months.[7] Martion and french (1987) show that short-term implied volatilities are largely insensitive to the level of the interest rate, so this approximation should not affect our results. Call options have been used for the Deutsche Mark, and Japanese Yen, because the interest rates on these currencies were lower than the U.S. interest rates during the sample period, and it would not have been optimal to exercise these calls early.

d. Macroeconomic Data

We use two kinds of U.S. macroeconomic data to control for changes in macroeconomic conditions.[8] We use announcement data and the surprise component for six vari-

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4) (1) The exercise price intervals are .01 cent for the Yen and 1 cent for the Deutsche Mark. (2) Expiration months are March, June, September, and December, plus two additional near-term months. (3) The expiration date is the Saturday before the third Wednesday of the month.

5) See Borensztein and Dooley (1987), Bodurtha and Courtadon (1987).

6) I would like to thank Mr. Robert DeGennaro at Solomon Brothers Inc for Kindly providing the data.

7) Federal Reserve releases H. 15 Statistical Releae, Selected Interest Rate.

8) I an grateful to Dr. Bonser-Neal for supplying data and article.

ables: the weekly change in the money supply M1 in billions of dollars, the nonthly merchandise trade balance in billions of dollars, the monthly percent change in industrial production, the monthly percent change in the consumer price index, the monthly percent change in the producer price index, and the monthly unemployment rate. Estimates of the surprise component of the macroeconomic announcements are computed by taking the difference between the announced macroeconomic value and the median forecast of the market participants surveyed by the Money Market Service. We also include the first difference of the squared percent change in the S&P 500 index.

3.2. Estimation Models

a. Cuurrency Options Pricing Model

In 1983, Garman and Kohlhagen[9] devised a formula, which adjusted the Black-Scholes model to accommodate the special featrues of foreign currency option valuation. The Garman-Kohlhagen model is similar to the Black-Scholes model (1973) with continuous dividends and the model is used to price European type currency options, i.e., those which can only be exercrsed at maturity. These differ from the options traded on the Philadelphia Stock Exchange (PHLX) which can be exercised any time up to and including the maturity date, i.e., American style options.

Assumptions:

1. Geometric Brownian motion governs the currency spot price: i.e., the differential representation of spot price movements is $dS=\mu S\,dt+\sigma S\,dZ$, where Z is the standard Wiener process. 2. The spot exchange rate denoted by S is assumed to be lognormally distributed over time. 3. Markets are frictionless. 4. Interest rates, both in the domestic and foreign markets, are constant.[10]

$$C_t=e^{-r_F T}S_t N(x+\sigma\sqrt{T})-e^{-r_D T}KN(x) \tag{3-1}$$

$$\text{where, } x=[\ln(S/K)+(r_D-r_F-(\sigma^2/2))T]/\sigma\sqrt{T} \tag{3-2}$$

9) See Garman and Kohlhagen (1983).

10) The analysis could be extended without much difficulty to stochastic interest rates. In this case, volatility parameters must be redefined to incorporate the variances and covariances of interest rate movements as well as spot price movements. However, we forego this extension in the interest rate of clarity.

The notation used here is as follows; S_t=the spot price of the deliverable currency as expressed domestic units per foreign unit. K=exercise price of the option in domestic units per foreign unit. T=time remaining until the expiration of the option. C_t=the price of a foreign exchange call option expressed in domestic units per fooreign unit. r_D=the domestic riskless interest rate. r_F=the foreign riskless interest rate. σ=the instantaneous standard deviation of the relative changes in the spot currency price. N(.)=standard cumulative normal distribution function. All the variables except the volatility of the exchange rates are known at the time of the option' s initiation. In the case of foreign currency the forward price is related to the ratio of the prices of riskless bonds denominated in the two currencies.

b. Estimation of Implied Volatilities[11]

The implied volatilities of the spot exchange rate from option prices information that is useful for forecasting future exchange rate volatility. The implied volatility is the unique volatility that equates the model price of an option with an observed market price of the option-given market observations on the spot rate and the domestic and foreign interest rates, and given the strike price and term-to-maturity of the option. It can be viewed as the current best consensus estimate by the market participants regarding future volatility of the spot exchange rate over the time to expiration, because it is calculated from actual option prices, it should reflect all available market information. Since no explicit equation for standard deviation cna be obtained from our model, numerical search procedures must be used.

First an initial guess for standard deviation is made, and substituted into garman-Kohlhagen equation. If the computed option pired is too large (small), then a smaller (larger) value for standard deviation will be used. Different options on the same underlying foreign currency may result in different implied volatilities. In the empirical study here, we obtain the daily implied parameters estimates for a foreign currency by minimizing the sum of squared deviations between market prices and model prices of the option trades on the same currency of the previous day.

From the option vlauation formula, Harvey and Whaley (1992a) specify the following

11) SAS and financial program are used.

model:

$$y=g(S, X, T-t, r_d, r_f, \sigma) \tag{3-3}$$

where, y= price of option, X=exercies pirce of option, S=spot exchange rate, T-t= time remaining to option expiration, r_d= domestic interest rate, r_f= foreign interest rate, σ= volatility of spot price, Since all the varalbes, except for the volatility variable, are known at the time of option valuation, we can compute the implied volatility by inverting the formula (3-1) to obtain:

$$\sigma=g^{-1}(y, S, S, T-t, r_d, r_f), \tag{3-4}$$

We can solve for the implied exchange rate volatility that equates the theoretical value, given the current price of the option, the spot exchange rate, etc. Thus, we consider the implied exchange rate volatility can obtained from the following equation:

$$y_i=g(S_i, X_i, (T-t)_i, r_{di}, r_{fi}, \sigma_i)+\epsilon_i \tag{3-5}$$

where, y_i denotes the observed market price of the i-th at-and near-the money option and ϵ_i is the error term, Equation (3-5) shows that model price of the currency options price can be computed using the spot exchange rate, the exercise price of the option, the time remaining to option expiration, the domestic interest rate, the foreign interest rate and the volatility of the option. The implied volatility is the volatility that equates the model price and the observed market price. We can calculate implied volatility with an iterative procedure using a Newton-Raphson approximation technique.

In order to eliminate the problems associated with deep in or out of the money option contracts, we use the option contracts which is closest to at the money. Many researchers show that there is a fundamental inconsistency with using implied volatility to capture ex ante volatility changes, because the option pricing model utilized assumes a constant volatility over the life of the option, or, at most, that volaility is a deterministic function of time.

To reconcile this, we conduct tests using those option contracts that are nearly at-the-money(i.e., exhibiting a spot exchange rate to exercise price ratio near unity). Such conrtacts have option prices that are nearly linear in the standard deviation;[12] consequently, the volatility estimate derived from a nonstochastic model should reflect the average volatility that is expected to prevail over the life of option.

3.3. GARCH Model

A GARCH model will be used to examine the effect of intervention on the level of the exchange rate variance to examine the intervention effect on the change of variances in implied volatility. Many study results show that foreign exchange rates have time varying volatilities. We can examine the time varying volatility as an empirical regularity of exchange rate behavior using the GARCH model, because, the GARCH model describes heteroscedasticity of foreign exchange rate successfully.[13] We formulate two kinds of GARCH models, that is, we investigate effects of days and Fed' s intervention. After that, we include macro data, implied volatility and other two interventions. The GARCH-in-mean model of the DM and YEN exchange rates for our study is specified as:

$$\Delta s_t = \beta_0 + \Sigma_{i=1,4}\,\beta_i DAY_{it} + \beta_5 US_{j,t-1} + \beta_6\sqrt{h_t} + e_t \tag{3-6}$$

$$e_t \mid \Omega_{t-1} \sim N(0,\ h_t) \tag{3-7}$$

$$h_t = \alpha_0 + \alpha_1 e^2_{t-1} + \alpha_2 h_{t-1} + \Sigma_{i=1,4}\,\beta_i DAY_{it} + \beta_5 US_{j,t-1} \tag{3-8}$$

$$\Delta s_t = \beta_0 + \beta_1 US_{j,t-1} + \beta_2 BJI_{j,t} + \beta_3 DAY_t + \Sigma_i{}^6{}_{=1}\gamma_i MACROD_{it} + \Sigma_i{}^6{}_{=1}\delta_k \mid MACROS_{kt} \mid + SP_t{}^2 + \ln(ISD(\$/j)_{t-1}/ISD(\$/j)_{t-2}) - \beta_4\sqrt{h_t} - e_t \tag{3-9}$$

$$e_t \mid \Omega_{t-1} \sim N(0,\ h_t) \tag{3-10}$$

$$h_t = \alpha_0 + \alpha_1 e^2_{t-1} + \alpha_2 h_{t-1} + \beta_1 US_{j,t-1} + \beta_2 BJI_{j,t} + \beta_3 DAY_t + \Sigma_i{}^6{}_{=1}\gamma_i MACROD_{it} + \Sigma_i{}^6{}_{=1}\delta_k \mid MACROS_{kt} \mid + SP_t{}^2 + \ln(ISD(\$/j)_{t-1}/ISD(\$/j)_{t-2}) \tag{3-11}$$

12) See Stein (1989). In the case of at-the-money options, Jorion (1994) also finds that implied volatility from a Black-Scholes model and a stochastical model are similar.

13) See Hsieh (1988a).

From the above equations (3-6, 3-9), 0st is the value of log-change in the DM or YEN spot exchange rares between period t-1 and t, DAY_{it} are day of the week dummy variables(i.e., $DAY_i=1$ on Monday), US_{it-1} is a variable showing actual federal Reserve intervention, BJI_{it} shows reported intervention by Bundesbank or Bank of Japan[14] $MACROD_{it}$ shows macroeconomic variables, i.e., money supply(I1), the trade deficit, industral production, the producer price index (PPI), the consumer price index (CPI), and the unemployment rate. Since the money supply is announced at 4:30 p.m., after the closing time of the PHLX, we include it announcement t-1 in our regression. Except the weekly M1 announcement data set, others are monthly announcement data. $MACROS_{kt}$ indicates the surprise component of each macroeconomic variable k, for k=1 to 6, as measured by the difference between the announced value and the median value provided data set by the MMS.

SP_t^2 is the first difference of the squared percentage change of S&P 500 index, as measured by the first difference of the square of the log of a ratio of the S&P 500 indexed at 10:00 a.m. on day t to the S&P 500 index at 10:00 a.m. on day t-1. We use surprise component as absolute values. The conditional distribution of the disturbance term has a conditional normal distribution with mean zero and variance ht. The last explanatory variable in equations (3-6-,9) show for the possibility that changes in the conditional variance influence the conditional mean. Equations (3-7,10) indicate that the distribution of the error term is conditional on information available at time t-1. Equations, (3-8,11) represent the conditional variance, h_t, as a function of exogenous variables and intervention at time t respectively. The conditional variance of the log-price change is an autoregressive porcess of past residual square and past variances. The model also considers day-of-week effects in the conditional variance. The GARCH-in-mean model is estimated by maximum likelihood procedure using the Berndt, Hall and Hausman algorithm (1974).

14) Similar to Dominguez (1993) and Bonser-Neal and Tanner (1995), we use Federal Reserve intervention data at t-1, foreign intervention data at t, because, Federal Reserve intervention can occur any time during the day, so that the Federal Reserve at day t the intervention effect may not be reflected in the market at thesame day. The foreign intervention, however, can be reflected at the same day, because, the German market is six hours ahead of PHLX and Japan market is fourteen hours ahead of it.

Table 4-1

Statistics of the Log-Price Changes and the Unit Root Tests
Sample:February 23, 1987-December 31, 1989, n=665
(Daily DM and YEN Spot Exchange Rate)

	DM	YEN
Mean	0.0116	0.0156
Minimum	-0.0546	-0.0497
Maximum	0.0289	0.0888
Variance	0.5374	0.1049
Kurtosis	3.5744[a]	4.7953[a]
Skewness	-0.7628[a]	0.5658[a]
Test of Serial Dependence in Residuals		
Q(24)	39.07[b]	36.31[b]
Q2(24)	112.53[c]	129.62[c]
ADF t-statistic	-17.94[d]	-16.39[d]

a Denotes rejection of the null hypothesis of a normal distribution (see Judge et. al., 1988, p 891, for the definition and the asymptotic distribution of skewness and kurtosis). b,c Denotes significance at the 1% and 5% level respectively. d Significant at 1% level using Mackinnon critical values ADF t-statistic on α_1 is the Augmented Dickey Fuller test : $\Delta S_t = \alpha_0 + \alpha_1 S_{t-1} + \Sigma\delta\Delta S_{t-i} + \epsilon_t$ where st represents first lag of logarithm of the spot DM and YEN exchange rates.

Ⅳ. EMPIRICAL TESTS AND RESULTS

We will investigate the effects of central bank intervention. First, we will examine the effect of Federal Reserve intervention. After that, we will examine the effects of Federal Reserve, Bundesbank and Bank of Japan interventions on the levels of DM and YEN exchange rate volatilities in the sopt market, including the six macroeconomic variables, each surprise component and S&P 500 index in our GARCH model. Intervention to affect the trend movements in exchange rates can include "leaning against (or with) the wind" or maintaining target zones.Intervention to calm disorderly markets could include attempts to reduce the variance of exchange rates.

Table 4-1 shows descriptive statistics and the results of unit root tests of the log-price changes of the DM and the YEN exchange rates. Means are nt statistically different from zero. Each kurtosis and skewness is significantly different from those values of

Table 4-2

Daily Exchange Rate GARCH Model: Conditional Mean Equation

Sample: February 23, 1987-December 31, 1989, n=665.

$\Delta s_t = \beta_0 + \Sigma_{i=1,4} \beta_i DAY_{it} + \beta_5 US_{jt-1} + \beta_6 \sqrt{v_t} + e_t$

Variables	DM	YEN
Intercept	-0.0701	-0.026
	(0.085)	(0.081)
Monday	0.0121	0.0770
	(0.012)	(0.073)
Tuesday	0.0732	0.0739
	(0.061)	(0.067)
Wenesday	0.0834	0.0422
	(0.092)	(0.053)
Thursday	0.0814	0.0221
	(0.092)	(0.038)
Fed. Intervention	0.3481a	0.1782a
	(0.142)	(0.077)
Variance	0.0334	0.0412
	(0.035)	(0.045)

Notes: The dependent variable is the log change in the DM or YEN spot exchange rate between period t and t-1. DAY_{it} are day of the week dummy variables (DAY_{it}=1 on Mondays), US_{jt-1} is reported Fed intervention against currency J known at t. v_t shows variance. a Denotes significance at 5% level. Standard errors of the extimated parameters are in parentheses.

normal distribution. The skewness of the DM is negative however, that of the YEN is positive. The Ljung-Box Q^2 statistic shows that there is a linear dependence in log-price changes of the both exchange rates. The Q^2 statistic shows that there is a serial dependence in the square of the log-price changes of the both exchange rates. The ADF valus indicate rejecate of a null hypotheses that the changes of log-price are nonstationary. In other words, the frist differences of a logarithm of the DM and the YEN exchange rates are stationary. This table also shows that there exist serial dependence and heteroscedastic behavior in the first differences of a logarithm of both exchange rates.

Table 4-2 shows the results from the conditional-mean equation (3-6). They suggest that day-of-the-week effects are statistically insignificant for the both ex change rates.

The coefficients of the intervention variables are statistically significant with positive signs for all cases. Since our conditional-mean equation shows the effects of Federal Reserve intervention on the trend of spot DM and YEN exchange rates, the positive and significant estimated coefficients on the intervention variables indicate that Federal Reserve intervention on the DM and YEN raised both spot exchange rates during our sample period. these results show that on the day following a dollar supporting intervention policy the dollar fell in value. The Federal Reserve intervention policy of DM and YEN exchange rates could not reverse the trend of those exchange rate movements. Our study results coincide with those of Dominguez (1993). The effects of the conditional variance on the trend of spot exchange rates is positive, though insignificant. In other words, increases in the conditional variance did not affect the change in the DM and YEN exchange rate.

Following equation (3-6), we estimate equation (3-9), which shows the effects of three central bank interventions, macroeconomic variables, each surprise conponent and S&P 500 index. The results are shown table 4-3. These results show that the effects of intervention by tne Federal Reserve is positive and significant. Furthermore, the effects of reported interventions by the Bundesbank and the Bank of Japan are also positive and change in the S&P 500 volatility, are positive and significant for the both exchange rate.

From our expanded model, we find similar qualitative results as Dominguez.[15] She, however, does not include Bundesbank intervention. After adding macro data and Bundesbank intervention, however, we find that the Fereral Reserve, the Bundesbank, and the Bank of Japan intervention increased the DM and the YEN exchange rate volatilities significantly. Since our conditional-mean equation shows the effects of the Federal Reserve, the Bundesbank and the Bank of Japan intervention on the trend of spot DM and YEN exchange rates, the positive and significant estimated coefficients on the intervention variables indicate that their interventions on the DM and YEN raised both opot exchange rates during our sample periods. These results show that on

15) Dominguez finds 5% significance level for the DM and the TEN exchange rates for the Federal Reserve intervention, and 1% significancee level for the Bank of Japan intervention. From our expanded model, We, however, find 1% significance level for the three interventions.

Table 4-3

Daily Exchange Rate GARCH Model: Conditional Mean Equation

$$\Delta S_t = \beta_0 + \beta_1 US_{t-1} + \beta_2 BJI_{jt} + \beta_3 DAY_t + \Sigma_{i=1}^{6} \gamma_i MACROD_{it} + \Sigma_{i=1}^{6} \delta_k \mid MACROS_{kt} \mid + SP_t^2 + \ln(ISD(\$/j)_{t-1}/\ln(ISD)(\$/j)_{t-2}) + \beta_4 \sqrt{v_t} + e^t$$

(February 23, 1987-December 31, 1989, n=665)

Variables	DM	YEN
Intercept	-0.0252	-0.0761
	(0.057)	(0.066)
Fed Intervention Dummy	0.2651**	0.2731**
	(0.065)	(0.072)
Bundesbank Dummy	0.0953**	---
	(0.014)	---
Bank of Japan Dummy	---	0.0652**
	---	(0.019)
Holiday/Weekend Dummy	0.0835**	0.2871**
	(0.027)	(0.075)
M1 Annou. Dummy	0.0445	0.0623
	(0.053)	(0.055)
M1 Surprise	-0.1243	-0.1161
	(0.127)	(0.153)
Trad. Def. Annou. Dummy	-0.2743**	-0.1634**
	(0.071)	(0.026)
Trad. Def. Surprise	0.2329	0.2374
	(0.265)	(0.179)
Ind. Prod. Annou.Dummy	-0.1643	-0.1198
	(0.132)	(0.187)
Ind. Prod. Surprise	0.0847	-0.0354
	(0.069)	(0.024)
PPI Annou. Dummy	-0.0867	-0.0929
	(0.064)	(0.082)
PPI Surprise	0.2753**	0.1542*
	(0.044)	(0.074)
CPI Annou. Dummy	-0.1736**	0.1837
	(0.046)	(0.133)
CPI Surprise	0.2734	-0.2759
	(0.222)	(0.232)

Variables	DM	YEN
Unemp. Annou. Dummy	-0.0231	-0.2361
	(0.052)	(0.167)
Unemp. Surprise	-0.0441	-0.0734
	(0.066)	(0.069)
Change in S&P 500 Vol.	0.5735**	0.1473**
	(0.127)	(0.037)
Lagged Implied Vol.	-0.2352**	-0.3836**
	(0.029)	(0.038)
Variance	0.0134	0.1547
	(0.035)	(0.161)

Notes: Standard errors in parentheses, *=significant at 5% level, **=significant at 1% level. The dependent variables, the changes of spot DM and YEN exchange rates are from log(st/st-1), st shows sopt exchange rate at t. All independent values are used in absolute values, and all are multiplied by 100 except the laggeed implied volatility and S7P 500 volatility. Federal Reserve, Bundesbank and Bank of Japan intervention equal one if they intervene, and 0 otherwise. Holiday/Weekend dummy variable equals one jif observation falls on a Monday or the day after a holiday. For each macroeconomic variable, we use two kinds of variables: one is a dummy variable, the other is a surprise component. In a dummy variable, we use one if the value is announced, zero otherwise; and a surprise component(announced value-median of the expected value by MMS).

the day following a dollar supporting intervention policy, the dollar fell in value, i.e., their intervention policies of the DM and the YEN exchange rates could not reverse the trend of those exchange rates.

Table 4-4 shows the results of the conditional-variance equations (3-8). The first three explanatory variable show GARCH parameters (α_0,α_1,α_2). All three coefficients are highly significant, indicating that the GARCH parameters have explanatory power in our model. Especially, the lagged conditional variances, α_2, which are about 0.898 and 0.863 for the DM and YEN, respectively. This result shows that variance effects are highly persistent. Similar to Dominguez' s (1993) results from her 1987-91 sample, for the both DM and YEN, the estimated coefficients on the intervention varables are significant and positive, indicating that intervention increased volatilities, measured by the conditional variance, throughout our sample period. The day-of-the -week effects are positive and significant on Monday and Tuesday only, suggests that the exchange-rate volatility increased after holidays. Also, the values of Q^2 statistics for the standardized residuals of the GARCH model imply that the standardized residuals are not autocorrelated in their squared residuals.

Table 4-4

Daily GARCH Model: Conditional Variance Equation

Sample:February 23, 1987-December 31, 1989, n=665.

$h_t = \alpha_0 + \alpha_1 e^2_{t-1} + \alpha_2 h_{t-1} + \Sigma_{i=1,4}\ \beta_i DAY_{it} + \beta_5 US_{j,t-1}$

Variables	DM	YEN
Intercept	0.0793**	0.0174**
	(0.013)	(0.003)
GARCH Parameter(a1)	0.0831**	0.0762**
	(0.021)	(0.019)
GARCH Parameter(a2)	0.8982**	0.8631**
	(0.053)	(0.051)
Monday	0.2161*	0.2083*
	(0.092)	(0.089)
Tuesday	0.0376*	0.0407*
	(0.017)	(0.019)
Wednesday	0.0324	0.0298
	(0.044)	(0.083)
Thursday	0.0416	0.0362
	(0.034)	(0.067)
Fed Intervention	0.1384*	0.1841*
	(0.063)	(0.077)
Test of Serial Dependence in Standardized Residuals		
Q(24)	31.6	32.9
Q224)	17.7	16.4

Notes: DAY_{it} are day of the week dummy variables (DAY_{it}=1 on Mondays), $US_{j,t-1}$ is reported Fed intervention against currency j known at t. v_t shows variance. *=Denoted significance at 5% level. **=Denote significance 1% level. Standard errors of the estimated parameters are in parentheses.

After estimating (3-9), we estimate the conditional-variance equation (3-11), which includes the three central bank interventions, and the six macroeconomic variables, and the S&P 500 index. As shown table (4-5), which is similar to table (4-4), the first three explanatory variables show GARCH parameters (α_0,α_1,α_2), All three coefficients are highly significant, show that the GARCH parameters have explanatory power in our model. The lagged conditional variances, α_2, is about 0.869 and 0.848 for the DM and YEN, respectively. This result shows that variance effects are highly jpersistent. The results also show that the effects of secret intervention by the Federal Reserve, report-

Table 4-5

Daily GARCH Model: Conditional Variance Equation

Sample:February 23, 1987-December 31, 1989, n=665.

$$h_t = \alpha_0 + \alpha_1 e^2_{t-1} + \alpha_2 h_{t-1} + \beta_1 US_{J,t-1} + \beta_2 BJI_{j,t} + \beta_3 DAY_t + \Sigma_{i=1}^{6} \gamma_i MACROD_{it} + \Sigma_{i=1}^{6} \delta_k \mid MACROS_{kt} \mid + SP_t^2 + \ln(ISD(\$/j)_{t-1}/ISD(\$/j)_{t-2})$$

Variables	DM	YEN
Intercept	0.0208*	0.0123*
	(0.009)	(0.006)
GARCH Parameter(01)	0.0849**	0.0711**
	(0.049)	(0.039)
GARCH Parameter(02)	0.8694**	0.8483**
	(0.044)	(0.031)
Fed Intervention	0.2451**	0.2173**
	(0.073)	(0.049)
Bundesbank Dummy	0.3122**	---
	(0.081)	---
Bank of Japan Dummy	---	0.3143**
	---	(0.077)
Holiday/Weekend Dummy	0.0112**	0.0371**
	(0.002)	(0.009)
M1 Annou. Dummy	0.0331	0.0123
	(0.065)	(0.013)
M1 Surprise	-0.0542	-0.0312
	(0.035)	(0.034)
Trad. Def. Annou. Dummy	-0.0621*	-0.0349*
	(0.018)	(0.016)
Trad. Def. Surprise	0.0146	0.0331
	(0.023)	(0.036)
Ind. Prod. Annou. Dummy	-0.0023	-0.0012
	(0.019)	(0.002)
Ind. Prod. Surprise	0.0445	-0.0236
	(0.033)	(0.071)
PPI Annou. Dummy	-0.0023	-0.0037
	(0.022)	(0.052)
PPI Surprise	0.053**	0.045*
	(0.009)	(0.009)

Variables	DM	YEN
CPI Annou. Dummy	-0.0201*	0.0122*
	(0.009)	(0.004)
Unemp. Annou. Dummy	-0.0522	-0.0235
	(0.039)	(0.021)
Unemp. Surprise	-0.0035	-0.0013
	(0.003)	(0.002)
Change in S&P 500 Vol.	0.0275**	0.0332**
	(0.003)	(0.009)
Lagged Implied Vol.	-0.6621**	-07263**
	(0.078)	(0.063)
Test of Serial Dependence in Standardized Residuals		
Q(24)		33.7 32.1
$Q^2(24)$		14.5 17.3

Notes: Standard errors in parentheses. *= significant at 5% level, **= significant at 1% level. All independent values are used in absolute values. and all are multiplied by 100 except the lagged implied volatility and S&P 500 volatility. Fed intervention. Bundesbank and BAnk of Japan equal one if they intervene, and 0 else. Holiday/Weekend dummy variable equals one if observation falls on a Monday or the day after a holiday. For each macroeconomic variable, we use two kinds of variables: one is a dummy variable, the other is a surprise component. In a dummy variable, we use one if the value is announced. zero else; and a surprise compontnt (announced value-median of the expected value by MMS).

ed intervention by the Bundesbank and the Bank of Japan are positive and significant. Thus, we find that each intervention policies increased conditional variance of the exchange rate during our sample period. Besides those intervention variables, the weekend/holiday dummy, the PPI suprise, and change in the S&P 500 volatility, are positive and significant for the both exchange rates. The M1 surprise, the trade deficit announcement dummy and one lagged implied volatility are also significant but negative for the both exchange rates. The CPI announcement dummy is significant and negative for the YEN exchange rate, however, significant and positive for the DM exchange rate.

In contrast, the CPI announcement dummy is positive and significant for the DM and negative and significant for the YEN exchange rates. Since our conditional-Variance equation shows the capability of 'calm" disorderly markets, the results of positive and significant effects of the Federal Reserve, the Bundesbank and the Bank of Japan intervention on the conditional variance imply that those intervention policies

increased volatilities of the spot DM and YEN exchange rates during the post-Louvre period.

Ⅴ. CONCLUSION

At the Louvre meting, February 20, 1987, the G-7 countries (except Italy) agreed to stabilize the currency values around current levels through joint intervention. the intention of this paper was to examine whether the Federal Reserve, Bundesbank and the Bank of Japan' s interventions had effects on the levels of volatilities during the post-Louvre period. we find that each intervention policy increased conditional variance of the exchange rate during our sample period. Besides those intervention variables, some of macro variables are positive or negative and significant for the both exchange rates. Especially, lagged implied volatility is negative and significnatfor the both exchange rates. Since our conditional-variance equation shows the capability of "calm" disorderly markets, the results of positive and significant effects of the Federal Reserve, the Bundesbank and the Bank of Japan intervention on the conditional variance imply that those intervention policies increased volatilities of the spot DM and YEN exchange rates during the post-Louvre period.

A recent study can help explain our and Doninguez' s results. Krugman (1991) suggests that markets expect intervention at particular target exchange rates, and these expectations can stabilize the exchange rates within a known target range. He argues, therefore, that "known target rates" can reverse the trend of the exchange rates.[16] In our sample period, however, the U.S. Federal Reserve did not announce exchange-rate-target zones.[17] If market participants anticipated the Federal Reserve' s intervention to maintain a known target zone in the post-Louvre period, they would have incorporated this information into their expectations. We cannot rule out the possibility that if the

16) Klein (1991) also shows that the expectation of intramarginal intervention can stabilize exchahge rate volatility.

17) Because, at the Louvre meeting, finance ministers and central bank presidents indicated their willingness to stabilize exchange rates "around current level." Nonetheless, they did not seem to agree on a precise definition of target zones. Opinions varied about the central rates and about countries' ovligations give various percentage deviations from those central rates. See Funabashi (1988).

Federal Reserve announced an exchange-rate-target zone, intervention policy could have reduced the volatility of DM and YEN exchange rates during our sample period.[18]

In case of the Federal Reserve, another possible explanation for our result may be the conflict between the Federal Reserve and the Treasury on the issue of stabilizing foreign exchange rates in the exchange markets.[19] This conflict led the Federal Reserve to quit intervention. In 1989 the Treasury, not the Federal Reserve, dictated U.S. foreign exchange intervention policy.[20] This suggests that a number of the Federal Reserve Board members were uncomfortable with the heavy dollar selling intervention in the exchange markets in 1989, because the U.S. Federal Reserve' 2monetary policy was relatively contractionary during this period. Some governors were concerned that the U.S. Federal Reserve was sending the market mixed signals.[21]

As seen from our results, since the central bank intervention increased the levels of the both currencies' volatilities, we can conclude that the intervention policies were unsuccessful in attaining the goal to reduce both volatilities during the post-Louvre period.

18) Baillie and Humpage (1992) also makes this point.

19) Dominguez (1993) and Kaminsky and Lewis (1992) also make this points.

20) Inthe U.S., the Department of Treasury has an official jurisdiction over foreign exchange intervention policy. Practically, the Deparment of Treasury and the Federal Reserve jointly decide when the U.S. need to intervene in the exchange market, but on occasion a decision may be made by the Department of Treasury over the objection of the Federal Reserve. Even though the Deparment of Trasury cab mandate intervention policy, it is Federal Reserve of New York that actually implements the policy. So, we see that the Department of Treasury is responsible for setting exchange-rare policy, yet it does not have the instruments to affect the exchange rates. The Federal Reserve is not responsible for setting exchange-rate policy, yet its domestic monetary policy poerations have a major effect on the exchange rate. In other words, the Federal Reserve has the instrument that the Treasury needs.

21) See Dominguez (1993), Kaminsky and Lewis (1992).

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