AN EXAMINATION OF THE RELATIONSHIP BETWEEN RETURNS AND TRADING VOLUME IN THE CURRENCY FUTURES MARKET: A LINEAR AND NON-LINEAR APPROACH

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ABSTRACT

In this paper, the relationship between returns and trading volume is examined for four currency futures contracts for the period January 1, 1986 to April 30, 1997. Both linear and nonlinear dependence is investigated. The study first employs linear causality tests, finding that futures returns and volume have no predictive power for one another. However, since the series show evidence of nonlinear dependence, the GARCH model is then employed. These results show a significant relationship between the returns and volume for only two of the four currencies (Japanese yen and Swiss franc) tested. When the series are divided into two subsamples, the results of the GARCH tests point to a significant relationship for all currency futures regarding the prediction of returns from volume traded, although mainly in the second test period. In summary, the results show that trading volume can provide important information in return prediction using a nonlinear model but that the series do not exhibit homogeneous behaviour over the entire sample period. Further, the results support the sequential information arrival hypothesis only in few cases.

INTRODUCTION

The information value of trading volume is of interest not only to researchers testing and developing financial theories but also to practitioners making investment decisions. In futures markets, for example, hedgers enter futures contracts to stabilize their future income flows, with the amount traded being determined by their expectations of the futures price and of future spot price variability. This is particularly important with respect to the capital requirement of a firm involved in hedging using currency futures since the futures position is marked to market, the gains and losses being settled at the end of each trading day. If the firm's futures position is sustaining losses, it may need additional funds to meet margin requirements. As such, the ability to forecast futures price movements is crucial in knowing how much capital (e.g, additional funds) may be needed to maintain this futures position.

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Speculators will also determine the amount of volume to trade based on their expectations of futures price movements. Indeed, Foster (1995) suggests that changes in returns and trading volume, are both driven by the same directing variable. As such, the relationship between returns and trading volume is expected to be positively correlated and evidence of such a relationship in futures markets is reported in Comiskey et al. (1987), Bessembinder and Seguin (1993) and Fujuhara and Mougouè (1997).

In this paper, the relationship between currency futures price variability and trading volume is reconsidered. First, prior research is updated by using data which avoid the problems related to the removal of the daily price limit in 1985 which affected much prior work. Because the series exihibit nonlinear characteristics, the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) variance equation is used in addition to linear Granger causality tests as the basis for predicting return and volume, and market efficiency is re-tested to gauge whether the current trading volume can improve the ability to forecast currency futures price volatility in the currency futures market.

The remainder of this article is organised as follows. Section II provides a summary of previous work. Section III describes the sample data and methodology used. This is followed in Section IV by the empirical results. Section V concludes

SUMMARY OF PREVIOUS WORK

Theory

The existence of a causality relationship between trading volume and asset returns has received considerable attention. As noted by Martikainen and Puttonen (1996), two competing models attempt to provide theoretical explanations regarding the relationship between information arrival and the correlation between price variability and volume. The simultaneous information arrival hypothesis (SIM), first proposed by Clark (1973) and later extended by Najang and Yung (1991), suggests that there exists a positive contemporaneous relationship between these variables. In the framework of SIM, new information is received simultaneously in a single trading day by all investors who act upon it after revising their expectations. This implies that price and trading volume change synchoronously in response to new information. The implication is that, in SIM, there is no information in volume which can be used in forecasting futures returns and, likewise, there is no information in the futures returns which can be used in forecasting volume.

A second model, referred to as the sequential information arrival hypothesis (SEQ), was first discussed by Copeland (1976) and subsequently developed by Smirlock and Starks (1988). The assumption made by SEQ is that new information is not transmitted to all traders in a single day. Instead, information reaches one trader at a time and trading therefore occurs in sequence only after information is received by each trader. Consequently, each individual trader's response to the signal represents one of a series of incomplete or intermediate equilibria prior to the final complete information equilibrium, as opposed to SIM where full equilibrium is obtained immediately. The primary implication of SEQ is that return is potentially forecastable with knowledge of past trading volume and vice versa.

EVIDENCE

Studies of the price-volume relationship in futures markets are relatively few as compared to equity and foreign currency spot markets. Research in the area began with the work of Clark (1973) on the price-volume relationship in the daily cotton futures market. A positive relationship is shown to exist between the square of price change and aggregated volume. In the market for Treasury-bill futures, Tauchen and Pitts (1983) also report a positive relationship between the return and trading volume.

In contrast to the above, Najang and Yung (1991) further investigate the Treasury-bond futures markets using a GARCH model. Applying contemporaneous volume, they find that the correlation with price change is significant in only a few cases, a finding which the authors attribute to simultaneity problems. However, when lagged volume is used in the equation, the positive correlation becomes significant in all cases. A strong positive relationship between contemporaneous trading volume and price changes is also found by Bessmbinder and Seguin (1993) who analyse a cross section of contracts in agriculture products, metals, currencies and financial futures. Finally, Foster (1995) examines the volume-volatility relationship in oil futures markets. Using the general method of moments (GMM), he finds that volume is not an adequate proxy for the information flow even though there is positive contemporaneous relationship between volume and return.

In the currency futures markets, Grammatikos and Saunders (1986) use correlation and causality tests to examine the relationship between price variability and trading volume, discovering a strong contemporaneous relationship and providing some evidence of a sequential relationship between price variability and trading volume in the majority of cases. Laux and Ng (1993) employ a GARCH model and find evidence that the clustering of information, proxied by contemporaneous and lagged intradaily currency futures returns, has a significant impact on the volatility of foreign exchange rates. Similarly, Charath et.al (1996), using GARCH and Vector Autoregression (VAR) models, find a positive relationship between the level of futures trading activity and the volatility in exchange rate changes. In contrast, McCarthy and Najang (1993), employing a state-space model to test the impact of lagged futures trading volume on currency futures prices fail to provide conclusive evidence as no relationship was found between trading volume and price, per se but found a positive causal relationship between trading volume and absolute price change for most cases.

DATA AND METHODOLOGY

For the present study, the data consist of daily settlement foreign currency futures prices for the British pound (BP), German mark (DM), Japanese yen (JY) and Swiss franc (SF) from January 1, 1986 to April 30, 1997, together with their corresponding daily trading volumes. The data set was constructed from quotations on the International Monetary Market (IMM) of the Chicago Merchantile Exchange (CME) and obtained via Datasream. The delivery months for the IMM currency futures contracts are September, December, March and June. As in previous research, the settlement prices are from the nearby contract only, while trading volume is a continuous series obtained by summing over all open contracts and expressed in number of contracts traded.[1] Due to some variation in the number of observations for trading volume as contracts were not traded on certain days, the series yield observations of 2865 for both DM and SF, 2863 for BP, and 2861 for JY.

To gauge whether the results are robust over the sample period, two almost equal-length subperiods are partitioned. They are from January 1, 1986 to June 19, 1991 (i.e. the contract maturity date closest to the mid-point of the series) for subperiod I and June 20, 1991 to April 30, 1997 for subperiod II. The number of observations for the currency futures for both subperiods are reported in Table 1.

Following Smirlock and Starks (1988), the SEQ hypothesis is first examined using the linear Granger causality test. Examination of the dynamic relationships of Granger causality[2] between R_t, the return[3]

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[1] *The logarithm of volume Ln (Vol) is also used but the results (which are available upon request) were qualitatively unchanged.*

[2] *In this study, tests for Granger causality are performed with a lag-length specification based on the behaviour of the log-likelihood. The likelihood functions do not improve after lag 3, a finding similar to Martikainen et al (1994) in equity markets. This is confirmed by other selection criteria, including Akaike's information criterion (AIC) and the Bayesian estimation criterion (BEC).*

on day t and V_t, the volume traded on day t, involves ordinary least squares estimation of the following two full models (Granger, 1969):

$$R_t = \alpha_0 + \sum_{i=1}^{n} \alpha_i V_{t-i} + \sum_{j=1}^{n} \beta_j R_{t-j} + \varepsilon_t \tag{1}$$

$$V_t = \lambda_0 + \sum_{j=1}^{n} \lambda_j R_{t-j} + \sum_{i=1}^{n} \delta_i V_{t-i} + v_t \tag{2}$$

The following hypotheses are then tested: $\alpha_i = 0$ and $\lambda_j = 0$. If neither can be rejected, then R_t and V_t are independent series. If both are rejected, then there is bidirectional causality, i.e. feedback, between R_t and V_t. If only the hypothesis $\alpha_i = 0$ is rejected, then there is unidirectional causality running from V_t to R_t. On the other hand, if only $\lambda_j = 0$ is rejected, then the reverse is the case (i.e. there is unidirectional causality running from R_t to V_t).

For restricted models, α_i and λ_j are excluded in equations (1) and (2). Following Guilkey and Salemi (1982), the F-test is calculated as follows

$$F = [(SSE_r - SSE_f)/m]/[SSE_f/(N-2m-1)], \tag{3}$$

where SSE_r and SSE_f are sums of squared errors for the restricted and full models, respectively, N is the number of observations and m is the number of lags.

GARCH MODELLING OF VOLUME AND VOLATILITY.[4]

Besides the Granger-causality tests which assume linear dependence, the GARCH family of statistical processes is employed in order to investigate the nonlinear relationships between variables. Engle (1982) introduced the first autoregressive conditional heteroscedasticity (ARCH) model, which was later extended to a generalized specification by Bollerslev (1986). The proxy for futures exchange rate variability is the conditional variance from the GARCH (1, 1) model of returns. Numerous recent studies on US data of financial time series suggest that one lagged conditional variance term appears to model conditional variance adequately (see, for example, Hsieh, 1988; Akgiray, 1989; and McCurdy and Morgan, 1987). The conditional variance is given by the estimate h_t from the maximum likelihood estimation of the following model:

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[3] *Returns are calculated using the logarithmic transformation $R_t = \log(p_t / p_{t-1})*100$, where p_t and p_{t-1} are today's price and yesterday's price of futures currencies, respectively. The use of logarithmic price changes prevents nonstationary in the price level from affecting futures price variability.*

[4] *The approximate maximun likelihood algorithm of Berndt, Hall, Hall and Hausman (1974) is used for estimation procedure.*

$$R_t = \mu_{t-1} + \varepsilon_t \qquad (4)$$

$$\varepsilon_t \backslash \psi_{t-1} \sim N(0,h_t) \qquad (5)$$

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{1\,t-1}^2 + \beta_1 h_{t-1} \qquad (6)$$

where μ_{t-1} is the mean equation of R_t conditional on past information which is proxied by R_{t-1}, ψ_{t-1} is the information set at t -1, ε_t is a stochastic error conditional on ψ_{t-1} which is assumed to be normally distributed with zero mean and conditional (time varying) variance h_t. As such, GARCH models the conditional variance of the error term as a linear function of the lagged squared residuals and the lagged residual conditional variance. In order to estimate the incremental contribution of volume to currency futures price volatility and vice versa, we allow the inclusion of these exogenous variables in the conditional mean and variance utilising the GARCH models below.

Return Prediction:

$$R_t = \mu_{t-1} + \varepsilon_t \qquad (7)$$

$$\varepsilon_t \backslash \psi_{t-1} \sim N(0,h_t) \qquad (8)$$

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1} + \delta_1 V_{t-1} \qquad (9)$$

Volume Prediction:

$$V_t = \mu_{t-1} + \varepsilon_t \qquad (10)$$

$$\varepsilon_t \backslash \psi_{t-1} \sim N(0,h_t) \qquad (11)$$

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1} + \delta_1 R_{t-1} \qquad (12)$$

Thus, Eq. (7) predicts the return during the time interval t, where the conditional variance in Eq. (9) is a function of the volume traded during the time interval t-1. On the other hand, Eq.(10) predicts the volume traded during the time interval t, where the conditional variance in Eq. (12) is a function of return during the time interval t-1. Both models assume a conditional normal distribution for the error term ε_t given in Equations (8) and (11). In both models, α_0, α_1, β_1 and δ_1 are the coefficients to be estimated. If lagged trading volume and lagged return contain information, then we expect δ_1 to be positive and statistically significant and, thus, V and R are able to predict one another.

EMPIRICAL RESULTS

Summary statistics for returns and traded volume for each of the four currency futures contracts are given in Table 2. The Jarque-Bera (J-B) statistic provides a test of the null hypothesis of normality which is rejected at the 1% significance level for both returns and volume. The non-normality of the data is due to leptokurtosis, consistent with earlier studies on currency futures data.

Table 3 reports the autocorrelation of returns and volume using the Ljung-Box *Q*-statistics. In Panel A, the results show significant autocorrelation in returns for all currency futures, except for BP. (DM and SF autocorrelation peaks at lag 2 and JY at lag 6). Moreover, by employing the Ljung-Box portmanteau test statistic proposed by McLeod and Li (1983) on squared returns over 6, 12, and 30 lags to test for second-order dependence, an ARCH effect is detected as shown by the presence of serial correlation in all currency futures.[5] The above results indicate that autocorrelations of the squared return series are much higher than those in the return series which suggests that a large change is likely to be followed by another large change and also that a small change is likely to be followed by another small change. In summary, daily returns are found to be linear and nonlinear dependent, similar to Chatrath *et.al* (1996).

As for the volume series, V_t, all four currency futures are significantly autocorrelated at the 1% level as reported in Panel B of Table 3. The first-order autocorrelation of 0.3630, 0.6211, 0.5332 and 0.5003 for British pound, German mark, Japanese yen and Swiss franc, respectively, indicates that about 13%, 38%, 28% and 25% of volume in each currency futures contract may be predicted using yesterday's trading volume. Although the autocorrelations reduce as the number of lags increases, they remain significant particularly for DM, a finding similar to that reported by Bessembinder and Seguin (1993). Panel B further shows that linear and nonlinear dependence are found in all currency futures volume series as they are correlated through their first and second moment.

A. A linear test of feedback between volume and returns

The results of the Granger causality test between returns and volumes for the whole period (1986-1997) are reported in Table 4. In order to apply the standard Granger-casaulity tests, stationarity of variables is required. For returns, the Augmented Dickey Fuller (ADF) statistic is consistently

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[5] A Lagrange multiplier test due to Engle (1982) also rejects the null hypothesis of no ARCH effect based on the estimated TR2 statistics. Hsieh (1989) points out that the McLeod and Li Q-statistic is related to Engle's (1982) test for heteroskedasticity since the former uses the autocorrelation coefficients of squared returns while the latter employed the partial autocorrelation coefficients.

negative, rejecting the null hypothesis of nonstationarity at the 1% level. As for volume, the null hypothesis of non-stationarity is also rejected.[6] In order to capture the heteroscedasticity problem in the series, the consistent covariance matrix estimator of White (1980) is applied in computing the *t*-statistics and standard errors. No causality is detected either from returns to volumes or in the opposite direction as all *F*- value are insignificant at all levels. However, the F-statistics are consistently higher for the prediction of returns from volume than vice versa. As for the two subperiods, the results are summarized in Table 5. The Granger-causality tests give similar results for both subperiods. Except for BP in subperiod 2, no currency futures contract shows a significant causality relationship between the variables. Overall, the results imply that the return series, R_t, and the volume series, V_t, seem to have no predictive power for one another, i.e. they are independent, thus rejecting the SEQ hypothesis. These findings seem to contradict those of Grammatikos and Saunders (1986), and Bessembinder and Seguin (1993), who report a positive linear relationship between currency futures returns and volume. However, as argued by Fujuhara and Mougouè (1997) such findings may be spurious as they rely on the assumptions of linearity between returns and volume and a constant-variance residual term.

B. A nonlinear test of feedback between volume and returns.

As the distribution of returns and volume series suggest some evidence of nonlinearity, this study is extended by analysing the relationship between these variables using a nonlinear model. Following Najang and Yung (1991), lagged volume is entered into the GARCH variance equation as an exogenous variable in order to investigate whether it has significant information and predictive power for returns in the currency futures market. Similarly, the lagged return is entered into the GARCH variance equation to investigate its predictive power for volume.

Table 6 reports the results for the whole sample period. The return prediction is statistically significant for JY and SF at the 10% level only. As for volume prediction, however, the information flow as proxied by lagged returns is statistically insignificant at all levels for all currencies.

Tables 7 and 8 present the results of the return prediction and volume prediction for the first and second subperiod, respectively. For volume prediction, the results are the same as those for the whole period with all *t*- statistics being insignificant for both subperiods. Returns therefore contain no

[6] *The ADF(1) for returns and volume are -38.2926 and -26.7815 for BP; -39.2338 and -25.8562 for DM; -39.2163 and -22.2859 for JY; and -39.8692 and -23.7214 for SF.*

predictive ability for futures trading volume. The prediction of returns from volume, however, shows significant *t*- statistics for all currency futures, although in different subperiods. While the parameter estimate of BP in subperiod 1 is positive and statistically significant at the 5% level, the relationship does not continue into subperiod 2. On the other hand, the parameter estimates for DM, JY and SF are positive and significant in subperiod 2 only. Whilst indicating that lagged volume is able to predict returns in the currency futures market, the results clearly show that there exists considerable structural instability in the series.

Overall, the results reported here for currency futures are similar to those of Martikainen. Puttonen, Luoma and Rothovius (1996) who find no evidence of linear causality lagged relationship between stock returns and trading volume but report significant return prediction using nonlinear GARCH models.

SUMMARY AND CONCLUSION

The purpose of this paper has been to empirically examine the lagged relationship between returns and trading volume in the currency futures market and to investigate the implications of this relationship for the microstructure of this market during the period 1986-1997. Using a linear Granger-causality test, the only causal lagged relationship observed was for one of four currency futures contracts in the second subperiod examined. Employing a nonlinear GARCH model, however, we found significant return prediction for all currency futures although in different subperiods (BP in subperiod 1, and DM, JY and SF in subperiod 2). It can be concluded that lagged volume has valuable information content for return prediction, but only when nonlinearity is accounted for. However, the results show that the series do not exhibit homogeneous behaviour over the entire sample period.

In addition, contrast to the earlier finding in financial market (see, for example, Smirlock and Starks, 1988; Gallant *et. al.*, 1992), the results are inconclusive as the hypothesis of sequential information arrival (SEQ) is rejected in some cases but not rejected in others. The results seem to suggest that whilst lagged return contain no information on present volume, past volume may be helpful in predicting futures price changes in the currency futures markets only using nonlinear approach. However, this is not to suggest that the markets are therefore inefficient since the study does not formally test for efficiency of the market.

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Table 1: Number of Observations in Subperiods

Subperiod	BP	DM	JY	SF
I	1426	1426	1426	1426
II	1437	1439	1435	1439

Notes: BP = British pound; DM = German mark; JY = Japanese yen; SF = Swiss franc.

Table 2: Summary Statistics of Currency Futures Returns and Volumes.

	BP		DM		JY		SF	
	R_t	V_t	R_t	V_t	R_t	V_t	R_t	V_t
Mean	0.0036	12228	0.1161	34335	0.0158	23515	0.0113	20998
SD	0.7225	7057	0.7291	16263	0.7171	11363	0.8138	7970
SK	-.3350	3.109	-.0348	1.085	0.2267	1.080	0.0456	0.8268
KS	3.3842	23.56	2.0753	2.117	3.8458	2.046	1.7291	2.1730
Max	3.4748	100580	3.6013	128764	4.7533	90426	3.9271	77222
J-B	1415[a]	102402[a]	510[a]	1449.5[a]	1798[a]	2290.7[a]	351[a]	1816.4[a]

Notes: BP = British pound; DM = German mark; JY = Japanese yen; SF = Swiss franc. R_t and V_t are returns and volume series, respectively. SD, SK, KS, Max and J-B are standard deviation, skewness, kurtosis, maximum and Jarque-Bera, respectively. Kurtosis refers to excess kurtosis where 0 denotes normality. The J-B statistic follows a chi-square distribution with 2 degree of freedom, the critical values of $\chi^2(2)$ being 4.61, 5.99 and 9.21 for significance levels of .10, .05 and .01, respectively. a b c indicate significance at 1%, 5% and 10%, respectively.

Table 3: Autocorrelation Coefficient for Futures Returns and Volumes.

Panel A: Returns

Lags	BP	DM	JY	SF
1	-0.0056	0.0075	-0.0082	0.0133
	(-0.2412)	(0.3532)	(-0.3603)	(0.6170)
2	-0.0093	-0.0398[c]	-0.0311	-0.0458[a]
	(-0.4126)	(-1.9201)	(-1.4863)	(-2.3941)
3	-0.0064	0.0045	-0.0077	-0.0070
	(-0.2931)	(0.2157)	(-0.3707)	(-0.0353)
4	0.0141	0.0100	0.0067	0.0051
	(0.6660)	(0.4983)	(0.3337)	(0.2541)
5	0.0245	0.0038	0.0181	-0.0111
	(1.1532)	(0.1930)	(0.8350)	(-0.5651)
6	-0.0297	-0.3397	-0.0453[a]	-0.0285
	(-1.3935)	(-1.5694)	(-2.1695)	(-1.3099)
7	0.0100	0.0204	0.0186	0.0214
	(-0.4965)	(1.0286)	(1.0037)	(1.0483)
8	-0.0012	-0.0032	0.0275	-0.0059
	(-0.0586)	(-0.1601)	(1.2973)	(-0.2996)
9	0.0126	0.0257	0.0200	0.0208
	(0.5341)	(1.2656)	(0.9346)	(1.0627)
10	0.0263	0.0114	0.0661[a]	0.0135
	(1.2483)	(0.5137)	(3.2515)	(0.6108)
LB(6)	5.2671	8.3960	10.066	9.2899
LB(12)	8.2168	13.276	28.247[a]	13.090
LB(30)	35.372	39.230[c]	49.337[b]	36.138
$LB^2(6)$	87.777[a]	62.551[a]	47.108[a]	62.621[a]
$LB^2(12)$	152.99[a]	112.43[a]	75.060[a]	119.97[a]
$LB^2(30)$	323.99[a]	198.72[a]	133.47[a]	194.67[a]

Notes: BP = British pound; DM = German mark; JY = Japanese yen; SF = Swiss franc. LB(6), (12) and (30) refer to the Ljung-Box portmanteau statistic for returns and volume over 6, 12 and 30 lags, respectively, and LB^2 refers to the same test for squared returns. The figures in parentheses are t-statistics, computed using standard errors obtained from White's (1980) heteroscedasticity-consistent covariance matrix estimator. a b c indicate significance at 1%, 5% and 10%, respectively

Panel B: Volumes

1	0.3630[a] (11.58)	0.6211[a] (32.49)	0.5332[a] (28.78)	0.5003[a] (25.78)
2	0.2338[a] (8.9310)	0.5166[a] (27.89)	0.3885[a] (20.67)	0.3393[a] (16.75)
3	0.1848[a] (8.1782)	0.4807[a] (24.39)	0.3511[a] (17.82)	0.2927[a] (14.54)[a]
4	0.2116[a] (8.8473)	0.4672[a] (24.99)	0.3117[a] (16.06)	0.2973[a] (14.96)
5	0.1788[a] (8.4752)	0.4407[a] (22.17)	0.2858[a] (14.47)	0.2441[a] (11.70)
LB(6)	907.81[a]	4193[a]	2293.4[a]	1845.4[a]
LB(12)	1097.5[a]	6668.1[a]	3089.5[a]	2259.6[a]
LB2(6)	115.14[a]	2769.5[a]	1668.3[a]	1203.1[a]
LB2(12)	141.17[a]	4141.3[a]	2290.7[a]	1429.4[a]

Notes: BP = British pound; DM = German mark; JY = Japanese yen; SF = Swiss franc. LB(6) and (12) refer to the Ljung-Box portmanteau statistic for returns and volume over 6 and 12 lags, respectively, and LB^2 refers to the same test for squared returns. The figures in parentheses are t-statistics, computed using standard errors obtained from White's (1980) heteroscedasticity-consistent covariance matrix estimator. a b c indicate significance at 1%, 5% and 10%, respectively.

Table 4: Estimation Results of the Causality Tests. 1986-1997

Currency futures	Constant	R_{t-1}	R_{t-2}	R_{t-3}	V_{t-1}	V_{t-2}	V_{t-3}	R^2	Restricted F-test
	Information flow from volume to currency futures returns.(H_0: R_t is not Granger-caused by V_t)								
BP	0.0672[b] (2.0011)	-0.0072 (-0.3081)	-0.0089 (-0.3997)	-0.0093 (-0.4235)	0.780-6 (0.4324)	-0.278-5 (-1.5099)	-0.3084[c] (-1.6544)	0.0022	1.9179
DM	0.0521 (1.4267)	0.0080 (0.4283)	-0.0402[b] (-2.1503)	0.0055 (0.2918)	0.107-4 (0.9774)	-0.929-5 (-0.7781)	0.130-4 (-1.1863)	0.0029	1.1949
JY	0.0676[c] (1.8213)	-0.0078 (-0.3403)	-0.0313 (-1.4973)	0.0071 (-0.3419)	-0.424-6 (-0.2834)	-0.185-6 (-0.1157)	-0.154-4 (-1.0778)	0.0019	0.8463
SF	0.0373 (0.6574)	0.0125 (0.5835)	-0.0462[a] (-2.4254)	0.0023 (0.1141)	0.297-4 (1.2674)	-0.924-6 (-0.3752)	-0.324-4 (-1.5226)	0.0036	1.2616
	Information flow from currency futures returns to volume.(H_0: V_t is not Granger-caused by R_t)								
BP	6398.1[a] (18.65)	-237.72 (-1.6187)	-138.15 (-0.9313)	-41.82 (-0.2826)	0.0031[a] (9.5176)	0.0009[a] (3.8153)	0.0008[a] (3.8153)	0.1492	0.8969
DM	8.5407[a] (13.204)	0.1883 (0.6280)	-0.4171 (-1.3357)	0.1849 (0.5972)	0.0045[a] (18.78)	0.0013[a] (5.4486)	0.0016[a] (7.7198)	0.4300	0.8007
JY	8.0729[a] (16.76)	0.3704 (1.4531)	-0.0384 (-0.1564)	-0.0904 (-0.3765)	0.0043[a] (19.49)	0.0008[a] (3.9221)	0.0014[a] (6.8772)	0.3137	0.8173
SF	8.2001[a] (17.96)	0.1613 (0.9808)	-0.1890 (-1.2418)	0.1335 (0.8988)	0.0042[a] (18.89)	0.0007[a] (3.0773)	0.0011[a] (5.7042)	0.2711	1.0366

Notes: BP = British pound, DM = German mark, JY = Japanese yen, SF = Swiss franc.
R_t and V_t. are returns and volume series, respectively. The figures in parentheses are t-statistics, computed using standard errors obtained from white's (1980) heteroscedasticity-consistent covariance matrix estimator. [a b c] Indicates significance at 1%, 5% and 10%, respectively, for a two tail test.

Table 5: Estimation Results of the Causality Tests for the Subperiods.

***F*-Statistics.**

Information flow from volume on currency futures returns.				*Information flow from currency futures returns on volume.*			
H$_0$: R_t is not Granger-caused by V_t				H$_0$: V_t is not Granger-caused by R_t			
Subperiod 1: Jan. 1, 1986- June 19, 1991.							
BP	DM	JY	SF	BP	DM	JY	SF
0.1793	0.3448	1.7970	1.3714	1.7320	0.4288	0.3463	0.3408
Subperiod 2: June 20, 1991- April 30, 1997.							
BP	DM	JY	SF	BP	DM	JY	SF
2.5232[c]	1.1680	0.0851	1.1935	0.3258	1.6832	1.1967	1.1582

Notes: BP = British pound; DM = German mark; JY = Japanese yen; SF = Swiss franc.
R_t and V_t. are returns and volume series, respectively.
[a b c] Indicates significance at 1%, 5% and 10%, respectively.

Table 6: GARCH Models Parameter Estimates: January, 1986- April, 1997.

	Return Prediction				*Volume Prediction*			
	$R_t = \mu_{t-1} + \varepsilon_t$ $\varepsilon_t \mid \psi_{t-1} \sim N(0, h_t)$ $h_t = \alpha_0 + \alpha_1 \varepsilon^2_{t-1} + \beta_1 h_{t-1} + \delta_1 V_{t-1}$				$V_t = \mu_{t-1} + \varepsilon_t$ $\varepsilon_t \mid \psi_{t-1} \sim N(0, h_t)$ $h_t = \alpha_0 + \alpha_1 \varepsilon^2_{t-1} + \beta_1 h_{t-1} + \delta_1 R_{t-1}$			
	BP	DM	JY	SF	BP	DM	JY	SF
α_0	0.0028[a] (4.7271)	0.6870[a] (3.7580)	0.8344[a] (3.5010)	0.0039 (1.4075)	28113300[a] (6.9462)	74205700[a] (2.5852)	67621300[a] (3.5911)	96715000[a] (2.7032)
α_1	0.0329[a] (12.662)	0.0409[a] (8.5675)	0.0369[a] (9.2892)	0.0285[a] (6.9833)	0.3234[a] (11.946)	0.3373[a] (5.5949)	0.3679[a] (5.8288)	0.3988[a] (4.3456)
β_1	0.9617[a] (308.15)	0.9443[a] (137.50)	0.9397[a] (154.68)	0.9568[a] (153.15)	0.5604[a] (18.747)	0.6160[a] (10.091)	0.5446[a] (8.1608)	0.4152[a] (3.3121)
δ_1	0.0 (0.0)	0.341-07 (0.6317)	0.151-06[c] (1.9218)	0.272-06[c] (1.6801)	0.0 (0.0)	4826800 (0.0723)	17474000 (0.5499)	11132000 (0.4822)
Skewness	-.2456	0.0011	0.3082	0.0854	3.3229	1.0543	1.3545	1.0583
Kurtosis	2.7266	1.6123	3.2863	1.3592	25.608[a]	2.5103	3.6026	4.1787
LB(6)	6.2602	6.7078	7.2932	7.9288	25.987[a]	47.770[a]	32.124[a]	47.78[a]
LB(12)	9.2250	13.547	28.310[a]	15.524	37.781[a]	53.790[a]	47.232[a]	62.37[a]
$LB^2(6)$	6.0676	1.6860	4.0015	4.0289	9.5050	41.360[a]	25.582[a]	30.37[a]
$LB^2(12)$	9.9254	8.6902	8.7672	10.545	19.497[c]	47.640[a]	31.529[a]	34.83[a]

Notes: BP = British pound; DM = German mark; JY = Japanese yen; SF = Swiss franc. LB(6) and(12) refer to the Ljung-Box-Portmanteau statistic for standardized residuals on return and volumes over 6 and 12 lags, respectively. $LB^2(6)$ and $LB^2(12)$ refer to the same test for squared residuals. The figures in parentheses are t-statistics.[a b c] Indicates significance at 1%, 5% and 10%, respectively.

Table 7: GARCH Models Parameter Estimates for Subperiod 1: January 1, 1986- June 19, 1991.

Return Prediction					*Volume Prediction*			
$R_t = \mu_{t-1} + \varepsilon_t$ $\varepsilon_t \mid \psi_{t-1} \sim N(0, h_t)$ $h_t = \alpha_0 + \alpha_1 \varepsilon^2_{t-1} + \beta_1 h_{t-1} + \delta_1 V_{t-1}$					$V_t = \mu_{t-1} + \varepsilon_t$ $\varepsilon_t \mid \psi_{t-1} \sim N(0, h_t)$ $h_t = \alpha_0 + \alpha_1 \varepsilon^2_{t-1} + \beta_1 h_{t-1} + \delta_1 R_{t-1}$			
	BP	DM	JY	SF	BP	DM	JY	SF
α_0	0.0023 (0.7413)	0.0158^b (2.4073)	0.0258^a (3.2604)	0.03197^b (2.2353)	15414000^b (1.9776)	53322000 (1.1124)	19725500 (1.5697)	0.113256+09 (1.3278)
α_1	0.0239^a (4.9396)	0.0594^a (5.7741)	0.0472^a (5.6079)	0.0404^a (3.6271)	0.3160^a (3.8909)	0.3089^a (2.6849)	0.2824^a (3.6595)	0. 399^b (2.2291)
β_1	0.9566^a (102.53)	0.9079^a (52.370)	0.9055^a (43.462)	0.9145^a (32.136)	0.6002^a (6.0697)	0.6437^a (5.2122)	0.7000^a (9.5847)	0.4076 (1.5938)
δ_1	0.804-06^b (2.2259)	0.156-06 (0.7657)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	367761 (0.0048)	9577700 (0.2770)	6617400 (0.1876)
Skewness	-0.3622	0.0025	0.2423	0.0634	1.4523	0.5301	1.0354	0.7925
Kurtosis	1.9165	1.2954	2.1045	0.7860	4.6561	0.7182	2.2860	4.8348
LB(6)	8.3771	5.2120	3.0100	4.5743	15.844^b	44.83^a	33.071^a	26.283^a
LB(12)	11.861	13.630	10.982	9.0264	20.848^c	50.479^a	39.195^a	29.805^a
LB2(6)	2.0296	3.7700	5.0287	12.052^c	9.6291	41.604^a	22.569^a	22.564^a
LB2(12)	9.0544	11.846	9.5431	18.126	16.910	46.829^a	31.816^a	25.828^b

Notes: BP = British pound; DM = German mark; JY = Japanese yen; SF = Swiss franc. LB(6) and(12) refer to the Ljung-Box-Portmanteau statistic for standardized residuals on return and volumes over 6 and 12 lags, respectively. $LB^2(6)$ and $LB^2(12)$ refer to the same test for squared residuals. The figures in parentheses are t-statistics.[a b c] Indicates significance at 1%, 5% and 10%, respectively.

Table 8: GARCH Models Parameter Estimates for Subperiod 2: June 20, 1991- April 30, 1997.

Return Prediction					*Volume Prediction*			
$R_t = \mu_{t-1} + \varepsilon_t$ $\varepsilon_t \mid \psi_{t-1} \sim N(0, h_t)$ $h_t = \alpha_0 + \alpha_1 \varepsilon^2_{t-1} + \beta_1 h_{t-1} + \delta_1 V_{t-1}$					$V_t = \mu_{t-1} + \varepsilon_t$ $\varepsilon_t \mid \psi_{t-1} \sim N(0, h_t)$ $h_t = \alpha_0 + \alpha_1 \varepsilon^2_{t-1} + \beta_1 h_{t-1} + \delta_1 R_{t-1}$			
	BP	DM	JY	SF	BP	DM	JY	SF
α_0	0.0025[a] (3.6670)	0.0019 (1.5171)	0.0070[b] (2.5012)	0.0001 (0.0325)	85428000[a] (5.5845)	0.1307+09[b] (2.3261)	0.15489+09[a] (3.84618)	10279100[b] (2.3937)
α_1	0.0350[a] (10.915)	0.02847[a] (5.9141)	0.0371[a] (5.9176)	0.0255[a] (5.3452)	0.3808[a] (9.3635)	0.3687[a] (4.2232)	0.4367[a] (4.6131)	0.3812[a] (3.5556)
β_1	0.9592[a] (246.67)	0.9594[a] (136.87)	0.9339[a] (115.82)	0.9631[a] (149.35)	0.2929[a] (3.9029)	0.5683[a] (6.2149)	0.3325[a] (3.0806)	0.3906[b] (2.5337)
δ	0.0 (0.0)	0.100-06[c] (1.8448)	0.309-06[a] (2.8085)	0.359-06[c] (1.8082)	0.0 (0.0)	57143000 (0.4342)	57695000 (1.1332)	14618500 (0.4076)
Skewness	-0.0273	0.0144	0.3978	0.1231	3.5551	1.1434	1.5372	1.2741
Kurtosis	3.5810	1.9721	4.3939	1.9066	26.530	2.2449	4.0815	3.9332
LB(6)	20.283[a]	11.159	14.343[b]	9.3195	17.002[a]	14.368[b]	14.668[b]	28.441[a]
LB(12)	24.334[a]	15.509[a]	28.019[a]	16.852	35.001[a]	19.886[c]	27.025[a]	41.329[a]
LB2(6)	6.8946	4.4350	2.7239	12.122	3.6064	15.344[b]	11.364	18.741[a]
LB2(12)	9.4606	9.6160	7.3914	18.663[c]	11.906	20.635[c]	15.585	28.449[a]

Notes: BP = British pound; DM = German mark; JY = Japanese yen; SF = Swiss franc. LB(6) and(12) refer to the Ljung-Box-Portmanteau statistic for standardized residuals on return and volumes over 6 and 12 lags, respectively. $LB^2(6)$ and $LB^2(12)$ refer to the same test for squared residuals. The figures in parentheses are t-statistics. [a b c] Indicates significance at 1%, 5% and 10%, respectively.