Volatility, Global Information, and Market Conditions: A Study in Futures Markets

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This study examined the behavior of return volatility in relation to the timing of information flow under different market conditions influenced by trading volume and market depth. We emphasized information flow during trading and nontrading periods that may represent domestic and offshore information in the global trading of currencies. Test results show that volatility was negatively related to market depth; that is, deeper markets had relatively less return volatility. Additionally, the effect that market depth had on volatility was superseded by information within trading volume. Test results focusing on the timing of information flow reveal that in low-volume markets, the volatility of nontrading-period returns exceeded the volatility of trad-

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ing-period returns. However, when trading volume was high, this pattern was reversed and conformed to the observations of earlier articles. Our findings proved to be robust across time, different currency markets, and different measures of return volatility. We also observed a trend toward greater integration between foreign and U.S. financial markets; the U.S. market increasingly emphasized information from nontrading periods to supplement information arriving during trading periods. Jrl Fut Mark 21:173–196, 2001

INTRODUCTION

Research has produced relatively few comprehensive studies on the behavior of return volatility under different market conditions comprising trading volume and market depth. Instead, studies have focused on the relation between the behavior of return volatility and the flow of information, with two distinct lines of research forming. One group has emphasized the role of trading volume as a proxy for information. Recent empirical studies, such as those by Jones, Kaul, and Lipson (1994b); Bessembinder and Seguin (1993); and Gallant, Rossi, and Tauchen (1992), have documented a strong, positive relation between return volatility and volume.[1] They have implied that a greater amount of information, embedded in volume, yields greater volatility. The second group has examined the pattern of return volatility in different trading environments and the impact on return volatility from the timing of information flow. These studies have shown dramatically higher return volatility during the trading hours of a market than when trades do not occur (French & Roll, 1986; Jones, Kaul, & Lipson, 1994a; Oldfield & Rogalski, 1980; Stoll & Whaley, 1990). The joint implication from these areas of research is that return volatility is positively related to the level of volume during the trading hours of financial markets and that a corresponding decrease in volatility occurs during nontrading hours.

The relation between trading volume and return volatility may be significantly affected by market depth, which studies suggest determines the ease and speed of transactions. The theoretical model in Kyle (1985) suggests that a deep market helps create market conditions that reduce price pressures when trading provides new information. Although lower return volatility may frequently exist in deep markets that facilitate trading activity, Kim and Verrecchia (1994) argued that low depth need not

[1]Other theoretical works that examined the positive relationship between volatility and volume referred to the mixture of distribution hypothesis described in Andersen (1996), Gallant et al. (1992), and Tauchen and Pitts (1983).

imply fewer trades. Although overall volume may not be affected, they proposed that low depth may increase the difficulty for large trades to occur smoothly and may lessen the speed of information transmission to the market. The propositions of these theoretical articles were supported by Bessembinder and Seguin (1992, 1993), who documented an inverse relationship between price volatility and market depth in their analysis of futures contracts.[2] The overall findings from these studies suggest that market depth and trading volume have opposite relations with the behavior of return volatility. However, previous research has not thoroughly explored the confounding effects of volume and depth that would explain the behavior of volatility under different market conditions, such as high trading activity in a low-depth market or low trading in a deep market.

In this study, we integrated the two streams of research and examined the interactions between trading volume, market depth, and return volatility. We analyzed the behavior of return volatility in the context of distinct market conditions, characterized by different levels of trading volume and market depth. Thus, we assessed the relative importance that these market variables have on return volatility. Our findings should help market participants better understand the intricate relations that market conditions have with the behavior of returns. We also analyzed the pattern in return volatility during trading and nontrading periods when the flow of information may reflect domestic and offshore sources. Thus, our analysis provides new evidence about changes in information flows across markets.

Research on return volatility has found a consistent return pattern that coincides with the presence and absence of trading activity. Oldfield and Rogalski's (1980) theoretical model recognizes the primary role of new information in determining the level of volatility during trading and nontrading periods. The authors proposed that information released during trading hours has a greater impact on volatility than information arriving during nontrading hours. French and Roll (1986), Stoll and Whaley (1990), and Jones et al. (1994a) empirically supported their propositions. Additionally, Harvey and Huang (1991) and Lin, Engle, and Ito (1994) studied internationally traded assets and observed similar volatility patterns. They also found that domestic information induced greater return volatility than foreign information. Thus, the timing and source of information significantly affected return volatility, although market depth was not included in these studies.

[2]Bessembinder and Seguin (1992, 1993) argued that open interest is a good proxy for market depth because open interest reflects the current willingness of futures traders to risk their capital in the futures position, which indicates the level of market depth.

The insights of these earlier articles into the behavior of return volatility in trading and nontrading hours may not reflect recent changes wrought by the rapid trend toward global linkage among financial markets. With continued market deregulation throughout the world and advances in information technology, globalization among markets may significantly increase the flow of offshore information to domestic markets, especially during nontrading hours. As a result, closer ties among the financial markets of the world may produce a greater, worldwide flow of information that may alter the patterns of return volatility during trading and nontrading periods and the historical relations between return volatility, volume, and depth.

In this study, we observed strong, distinct patterns of return volatility across market conditions that had different combinations of trading volume and market depth. With our tests, we found that market depth had its greatest relationship with return volatility during high-volume periods and that this occurred primarily through its interaction with trading volume. Test results also show that return volatility was greater during nontrading periods than during trading periods with low volume, implying that offshore information dominated domestic information in its association with volatility. It was only during high-volume periods that return volatility during trading hours exceeded the volatility of nontrading periods, a finding consistent with French and Roll (1986). We also observed a trend toward the U.S. market's increased use of information from nontrading periods that was reflected in changes in the behavior of return volatility, a pattern that implied greater integration among financial markets.

The remainder of this article proceeds as follows. In Data and Measurement of Variables, we present the data and measurements of variables. In Volatility Estimation and Evidence, we discuss the methodology. In Comparison of Trading-Hour and Nontrading-Hour Volatilities, we compare the volatility behavior of trading and nontrading returns. In Impact of Nontrading-Period and Trading-Period Information Flows Over Time, we extend the empirical analysis, and in the final section, we provide concluding remarks.

DATA AND MEASUREMENT OF VARIABLES

In this study, we examined the relationships between return volatility, trading volume, and market depth by using daily price, volume, and open-interest data from seven futures markets. The futures data were obtained from the Futures Industry Institute and consist of five currency futures prices (Canadian dollar, German mark, Japanese yen, pound sterling, and Swiss franc) and two interest-rate futures prices (3-month Eurodollar and U.S. Treasury bills [T-bill]). We selected futures prices from the nearby contracts that had the largest trading volume, thus tracking the activity of the market.[3] Additionally, our data span the period from June 1982 through March 1994.

We used price data to construct three daily returns: trading, nontrading, and close–close. We computed the trading-period return (open–close) at time t as $\log(P_{c,t}/P_{o,t})$, where $P_{c,t}$ is the closing price at time t and $P_{o,t}$ is the opening price at time t. Similarly, we computed the nontrading return (close–open) at time t as the $\log(P_{o,t}/P_{c,t-1})$ and the close–close return at time t as $\log(P_{c,t}/P_{c,t-1})$. We included the close–close return in our analysis for comparative purposes because, in earlier articles, only this return measure was used.

We formed a stationary time series of trading volume by incorporating the procedure described in Campbell, Grossman, and Wang (1993), who used a 100-day backward moving average:

$$V_t = \frac{LV_t}{\left(\sum_{i=1}^{100} LV_{t-i}\right)\Big/100}$$

where LV_t is the log of the trading volume at time t. This volume metric captures the change in the long-run movement in the trading volume.

Kyle (1985) suggested that *market depth* is the order flow required to move prices by one unit. As the order flow changes, the open interest of the futures contracts will also change endogenously. The level of open interest represents a measure of trading activity that also reflects the willingness of traders to assume positions of capital risk in the presence of price volatility. Following the example of Bessembinder and Seguin (1992, 1993), we used open interest as a proxy for market depth. To create a stationary series for open interest, we applied the same transformation procedure used for trading volume.[4]

Foreign currency markets operate 24 hr each day throughout the world, whereas the U.S. currency futures market closes at the end of its trading day. With the global spot markets remaining in operation, a continual flow of information occurs during the U.S. nontrading hours of

[3]For example, when the number of transactions declined as the nearby contract approached maturity, we selected data from the next contract because there was a greater volume of transactions.

[4]We experimented with a 20-trading moving average to compute the volume and open-interest metrics. The empirical results were similar and are not reported here.

the futures markets. This pattern contrasts with the diminished information flow experienced by the equities examined by French and Roll (1986) and Lin et al. (1994). Therefore, we expected the information flow from global spot markets to reflect a relatively larger proportion of total information.

We also included two interest-rate futures to determine whether our findings could be generalized to other financial assets. The Eurodollar, although influenced substantially by domestic U.S. news, is an international asset that is traded globally. Thus, price changes in the Eurodollar more readily may reflect both world news and changes in risk premiums among different Eurocurrency rates in the international financial market. Conversely, the 3-month U.S. T-bill is a prima facie domestic asset that may be less affected by offshore information that arrives during nontrading hours.[5] Thus, our sample included a wide spectrum of financial assets that ranged from largely domestic to purely international in nature.

Table I reports summary statistics both for the trading, nontrading, and close–close returns and the detrended measures of trading volume and market depth. The mean trading returns were higher than the mean nontrading returns, with the exception of the T-bill. Greater volatility existed among the trading returns than among the nontrading returns, with the exception of the T-bill, and this volatility pattern is consistent with the finding that, on average, more information is released during the trading hours of the futures markets.[6] The contrary behavior of the T-bill futures price suggests that important interest-rate information is released after the closing hours of the futures market. Although the T-bill futures market closes at 3:00 p.m., its spot market is actively trading in New York until 5:00 p.m. Eastern Standard Time. Thus, new information may be released after the closing hour of the futures market but before the closing hour of the spot market.[7]

VOLATILITY ESTIMATION AND EVIDENCE

To examine the behavior of volatility in the context of different market conditions, we first measured daily return volatility with a two-pass pro-

[5]U.S. T-bill rates are actually linked to interest rates in other countries. In reality, it is difficult to find a financial asset that is immune to foreign influence in today's global market.

[6]We conducted augmented Dickey–Fuller unit root tests on the volume and open-interest metrics. The test results rejected the unit root; thus, these series were stationary.

[7]The release of information after the closing of the spot market is particularly important for interest-rate markets. As a result, a device called a *wild card option* is utilized for short positions to exploit the spot information available after the closing of the futures market in the Treasury bond futures contracts.

TABLE I

Summary Statistics: Trading, Nontrading, and Close–Close Returns; Volume; and Market Depth

Panel A: Return Statistics (× 100)

	Trading Period			Nontrading Period			Close–Close		
	M	*SD*	*Autocorrelation Lags*	*M*	*SD*	*Autocorrelation Lags*	*M*	*SD*	*Autocorrelation Lags*
CD	0.0055	0.2218	1	−0.0029	0.1976	1	−0.0023	0.2903	4
DM	0.0287	0.5714	1	−0.0148	0.4855	1	0.0139	0.7516	1
JY	0.0187	0.4881	1	0.0120	0.4770	1	0.0308	0.6861	4
PS	0.0246	0.5904	1	−0.0289	0.5037	3	−0.0043	0.7884	2
SF	0.0176	0.6456	4	−0.0058	0.5230	1	0.0118	0.8355	2
ED	0.0019	0.1010	1	0.0018	0.0998	2	0.0037	0.1349	1
TB	0.0014	0.0892	1	0.0020	0.0916	0	0.0034	0.1204	0

Panel B: Volume and Depth Statistics, Detrended (× 100)

	Trading Volume			Market Depth		
	M	*SD*	*Autocorrelation Lags*	*M*	*SD*	*Autocorrelation Lags*
CD	0.0051	0.6054	4	0.0184	0.2702	2
DM	0.0333	0.3715	9	0.0338	0.2347	1
JY	0.0246	0.4625	6	0.0255	0.2601	2
PS	0.0169	0.4267	6	0.0166	0.2444	2
SF	0.0154	0.3603	1	0.0212	0.2210	8
ED	0.0955	0.5183	8	0.0832	0.17040	0
TB	−0.0359	0.5253	4	0.0027	0.2411	2

Note: Trading-period returns, nontrading-period returns, and close–close returns were computed on the basis of open–close, close–open, and close–close prices, respectively. Trading volume and market depth were transformed through a 100-trading-period moving average process. The autocorrelation lags column denotes the number of the 15 lags that were significant at the 5% level or higher. CD Canadian dollar; DM Deutsche mark; JP Japanese yen; PS pound sterling; SF Swiss franc; ED Eurodollar; TB 3-month U.S. Treasury bill.

cedure that was detailed in Schwert (1990) and Jones et al. (1994b). We first regressed the daily return on its own lags and day-of-the week dummy variables to adjust for the impact of autocorrelation and day-of-the-week effects. In the second-pass procedure, we used the absolute value of the first-pass regression residuals as proxies for return volatility. The first-pass procedure is estimated as

$$R_{it} = \sum_{k=1}^{5} a_{ik}D_{kt} + \sum_{j=1}^{15} b_j R_{i,t-j} + \varepsilon_{it} \tag{1}$$

where R_{it} is the return of asset i on trading t and the D_{kt} variables are the day-of-the-week dummy variables that adjust for differences in mean returns and for the weekend effect. We estimated the short-term movement in conditional expected returns by incorporating 15 lagged returns as regressors.[8]

Volatility Behavior and Its Relation with Volume and Market Depth

Our first test identified the overall relationship between volatility, volume, and market depth with the three measures of volatility. Thus, we identified how volume and depth independently affected volatility in the markets with different compositions of these market variables. We first estimated Equation 1 and then transformed ε_{it} in Equation 1 to represent volatility within trading (open–close), nontrading (close–open), and close–close returns. The absolute value of the ε_{it} proxies for the volatility measure of the three returns in the second-pass regression was found as follows:

$$|\varepsilon_{it}| = \alpha_i + \alpha_{im}M_t + \beta_{1i}V_{it} + \beta_{2i}D_{it} + \sum_{j=1}^{15} \rho_{ij}|\varepsilon_{i,t-j}| + \eta_{it} \quad (2)$$

where M_t is the Monday dummy variable equal to 1 for Mondays and 0 otherwise, V_t is the detrended trading volume at time t, and D_t is the market depth (open interest) at time t.[9] The ρ_{it} coefficients measure the autocorrelation in the volatility of asset i. We used a regression technique that adjusts for heteroscedasticity and autocorrelation in the residuals to estimate Equation 2 for all futures contracts.[10]

Table II reports the regression results from Equation 2 with volatility measures of trading, nontrading, and close–close returns. The general effects of volume and depth were similar across all return volatilities. We observed a strong, positive relation between volume and return volatility. Thus, an increase in volume increased return volatility, a finding consistent with Lamoureux and Lastrapes (1990) and those surveyed in Karpoff (1987). We also found an inverse relationship between market depth and volatility, which implies that greater depth mitigated return volatility. These results are consistent with Bessembinder and Seguin (1992, 1993).

[8]We experimented with different numbers of lags, and the results were robust across different lag lengths.

[9]We used the squared residual as another proxy for volatility and obtained the same test results. Additionally, we used a generalized autoregressive conditional heteroscedacity model, (GARCH) (1, 1) model, to examine the volatility behavior, and it produced similar results.

[10]We used a generalized method of moments to correct for heteroscedasticity and autocorrelation issues in the regression analysis.

TABLE II

Interaction between Return Volatility, Volume, and Market Depth (×100)

$$|\varepsilon_{it}| = \alpha_i + \alpha_{im} M_t + \beta_{1i} V_{it} + \beta_{2i} D_{it} + \sum_{j=1}^{15} \rho_{ij} |\varepsilon_{i,t-j}| + \eta_{it}$$

	Trading-Period Returns					*Nontrading-Period Returns*					*Close–Close Returns*				
	Constant (t-stat)	*Monday (t-stat)*	*Volume (t-stat)*	*Market Depth (t-stat)*	*Number of Lags (ε)**	*Constant (t-stat)*	*Monday (t-stat)*	*Volume (t-stat)*	*Market Depth (t-stat)*	*Number of Lags (ε)**	*Constant (t-stat)*	*Monday (t-stat)*	*Volume (t-stat)*	*Market Depth (t-stat)*	*Number of Lags (ε)**
CD	0.0688(11.29)	0.0123(1.95)	0.1017(19.08)	−0.0115(−1.11)	6	0.0585(8.80)	0.0253(3.60)	0.0605(11.97)	−0.0405(−3.16)	5	0.1049(11.99)	0.0314(3.65)	0.1526(19.75)	−0.0514(−3.41)	5
DM	0.2319(11.07)	0.0277(1.76)	0.44668(20.91)	−0.0923(−3.37)	10	0.1056(8.79)	0.1463(7.20)	0.2063(11.62)	−0.0846(−2.97)	8	0.3256(11.60)	0.1311(5.86)	0.5806(21.22)	−0.1521(−4.15)	7
JY	0.2001(13.06)	0.0053(0.40)	0.3467(18.59)	−0.1371(−6.25)	5	0.1091(9.12)	0.1103(6.25)	0.2032(11.94)	−0.0790(−3.27)	6	0.3486(14.99)	0.0948(4.36)	0.5012(19.21)	−0.2176(−6.96)	1
PS	0.1658(8.20)	0.0180(1.09)	0.4093(19.84)	−0.1653(−5.88)	8	0.0976(6.48)	0.1725(8.79)	0.2082(13.28)	−0.1268(−4.13)	9	0.2676(9.12)	0.1688(7.24)	0.5980(23.08)	−0.2926(−7.74)	8
SF	0.2724(10.53)	0.0389(2.17)	0.5052(19.80)	−0.0857(−2.63)	8	0.1158(8.61)	0.1384(6.19)	0.1687(8.26)	−0.0922(−2.62)	8	0.4195(12.51)	0.1421(5.68)	0.6306(19.18)	−0.1701(−3.91)	6
ED	0.0187(5.54)	0.0090(2.96)	0.0557(18.62)	−0.0133(−1.34)	6	0.0129(4.22)	0.0149(4.13)	0.0179(4.96)	−0.0119(−0.61)	6	0.0228(4.17)	0.0165(3.55)	0.0588(14.15)	−0.0385(−2.14)	5
TB	0.0129(4.18)	0.0034(1.10)	0.0369(15.16)	−0.0166(−3.94)	6	0.0124(4.25)	0.0120(3.54)	0.0135(3.06)	−0.0211(−3.91)	4	0.0153(2.92)	0.0111(3.02)	0.0411(10.90)	−0.0356(−5.51)	6

Note: The sample period was June 1982 to March 1994. The volatility of returns was regressed on volume and open interest along with Monday dummy (*M*) and 15 volatility lags with *t* values in parentheses. The standard error of the estimates was corrected for heteroscedasticity and autocorrelation. An asterisk (*) denotes the number of the 15 lags that were significant at the 5% level or higher. See Table I for the definitions of the abbreviations.

Comparison of Volatility among Volume–Depth Groups

The behavior of return volatility may vary under different trading environments if market conditions reflect different information flows. For example, return volatility may exhibit distinct behaviors in high-volume periods, depending on whether the market has low or high depth. Thus, we analyzed the interactive effect of volume and market depth on return volatility. We identified four markets that had different combinations of high and low levels of volume and depth by grouping trading volume and open interest into quartiles. Quartile 1, designated *L,* represents the smallest number of trades or order flows, whereas Quartile 4, designated *H,* represents the heaviest amount of trades or order flows. For example, an LH market has trading volume in the lowest quartile and depth in the highest quartile.[11] We emphasized these four market structures because they represent distinct tiers of volume and depth that also reflect conditions commonly experienced by traders in financial markets.

To obtain more information about the effects of market depth and volume on the behavior of return volatility, we conducted tests to determine the relative magnitude of the return volatility in each of the four market structures. Thus, we ranked the magnitude of return volatility across market conditions to make direct comparisons as market conditions changed. Earlier test results revealed that trading volume and market depth produced opposite effects on return volatility under most market conditions and that the magnitude of impact appeared to vary with market conditions. We estimated Equation 1 to obtain the proxy for volatility and then estimated the volatility in returns in the second pass as

$$|\varepsilon_{it}| = \alpha_i + \alpha_{im}M_t + \sum_{i=1}^{4} \beta_i Q_i + \sum_{j=1}^{15} \rho_{ij}|\varepsilon_{it-j}| + \eta_{it} \qquad (3)$$

where $|\varepsilon_{it}|$ is the absolute residual from Equation 1 and Q_{it} represents the *i*th quartile dummy variables for the four volume–depth combinations that are either equal to 1 or 0 for each of the four groups: low volume/low depth, low volume/high depth, high volume/low depth, and high volume/high depth. The variables M_t and ρ_{it} were defined and explained in Volatility Estimation and Evidence. The dummy variables allowed for a

[11]We identified four categories of volume and depth: LL represents the first quartiles for volume and open interest, LH represents Quartile 1 of volume and Quartile 4 of open interest, HL represents Quartile 4 of volume and Quartile 1 of open interest, and HH represents the fourth quartiles of volume and open interest.

comparison of the relative sizes in return volatility as the volume and depth conditions of the markets changed.

Test results, presented in Table III, show similar patterns in volatility across return measures in trading and nontrading periods and all futures markets. Trading volume appeared to dominate market depth in its impact on return volatility. As expected, market conditions with high trading volume had higher return volatility than markets with low volume.[12] Volatility was negatively related to market depth only for low-volume markets. For example, of the two low-volume markets (LL and LH), the market with high depth (LH) always had lower return volatility when the difference was statistically significant; the opposite never occurred. Among high-volume markets, greater volatility usually occurred with lower depth ($\beta_{hl} > \beta_{hh}$), suggesting that low depth added to market friction and increases return volatility during heavy trading.

Of the four markets examined, return volatility was greatest in the HL market (high volume/low depth), whereas the lowest return volatility (most negative coefficient) was in the LH market (low volume/high depth). Importantly, the tests showed that the impact of depth (liquidity) was less than the impact of volume. With depth, we observed differences in sign across trading volume, but with volume, liquidity had little impact on volatility. [13]

Overall, these findings demonstrate that during periods of high trading volume, low market depth produced greater market friction. Conversely, deep markets appeared to accommodate varying levels of trading activity without imposing the same price pressures that would occur in a market with low depth, especially when a lower level of trading activity occurred. Thus, the behavior of return volatility varied across market conditions.

COMPARISON OF TRADING-HOUR AND NONTRADING-HOUR VOLATILITIES

When trading for futures stops for the U.S. market, the currency spot market remains active in other parts of the world. Thus, the nontrading

[12]The coefficients for the volume–depth dummy variables, β_i, were negative for the two low-volume groups, LL and LH, whereas they were positive for the high-volume groups. The sign of the beta coefficients depended primarily on the volume grouping, implying that the positive volatility impact from the trading volume dominated the negative effect of market depth on the return volatility.

[13]We conducted tests for volatility differences among groups. We report only the results for the LL with LH and HL with HH groups; we found that there were statistically significant differences between the volatilities of the respective LL with HL and LH with HH groups. These results are not reported because of space constraints.

TABLE III

Return Volatility by Volume–Depth Combination

$$|\varepsilon_{it}| = \alpha_i + \alpha_{im}M_t + \sum_{i=1}^{4} \beta_i Q_i + \sum_{j=1}^{15} \rho_{ij}|\varepsilon_{it-j}| + \eta_{it}$$

	Constant (*t statistic*)	Monday (*t statistic*)	*LL* (*t statistic*)	*LH* (*t statistic*)	*HL* (*t statistic*)	*HH* (*t statistic*)	*F Test*, *LL* = *LH*	*F Test*, *HL* = *HH*	*Lag* (ε)
Panel A: Trading-Period Returns									
CD	0.0519 (8.01)	0.0058 (0.87)	−0.0477 (−8.91)	−0.0573 (−7.29)	0.0791 (4.98)	0.0981 (7.18)	—	—	6
DM	0.2166 (9.48)	0.0041 (0.25)	−0.1815 (−13.65)	−0.1636 (−8.49)	0.3471 (6.41)	0.2205 (6.92)	—	1	7
JY	0.1628 (9.67)	−0.0176 (−1.22)	−0.1267 (−11.07)	−0.1287 (−7.41)	0.3357 (5.71)	0.1272 (5.60)	—	1	5
PS	0.1542 (7.06)	0.0013 (0.08)	−0.1407 (−8.65)	−0.1735 (−9.75)	0.3964 (6.09)	0.1912 (6.00)	—	1	6
SF	0.2508 (8.99)	0.0018 (0.10)	−0.2091 (−13.09)	−0.2338 (−10.55)	0.3708 (6.50)	0.2191 (6.77)	—	1	7
ED	0.0180 (5.33)	−0.0031 (−1.04)	−0.0237 (−9.32)	−0.0245 (−4.47)	0.0616 (6.88)	0.0394 (6.52)	—	1	5
TB	0.0102 (3.08)	−0.0013 (−0.42)	−0.0147 (−4.86)	−0.0187 (−5.72)	0.0271 (3.66)	0.0231 (4.88)	—	—	8
Panel B: Nontrading-Period Returns									
CD	0.0492 (7.09)	0.0212 (3.02)	−0.0256 (−3.63)	−0.0516 (−8.24)	0.1034 (4.65)	0.0414 (4.04)	10	1	6
DM	0.0872 (7.14)	0.1361 (6.66)	−0.0168 (−0.87)	−0.0911 (−4.70)	0.1007 (2.32)	0.1422 (5.60)	5	—	9
JY	0.0963 (7.93)	0.0998 (5.53)	−0.0578 (−4.03)	−0.0976 (−4.63)	0.0399 (1.15)	0.1168 (4.60)	—	5	6
PS	0.0850 (5.33)	0.1672 (8.29)	−0.0587 (−3.34)	−0.1101 (−5.92)	0.2037 (3.70)	0.1491 (5.90)	—	—	8
SF	0.1023 (7.05)	0.1287 (5.82)	−0.0137 (−0.61)	−0.0773 (−3.67)	0.1479 (2.23)	0.1040 (4.05)	10	—	7
ED	0.0129 (5.05)	0.0108 (3.05)	0.0039 (0.59)	−0.0190 (−6.94)	0.0134 (1.54)	0.0172 (2.35)	5	—	6
TB	0.0118 (4.18)	0.0104 (3.11)	−0.0014 (−0.30)	−0.0129 (−5.20)	0.0100 (1.46)	0.0051 (0.85)	—	—	4
Panel C: Close–Close Returns									
CD	0.0715 (7.66)	0.0218 (2.41)	−0.0511 (−5.87)	−0.0707 (−8.11)	0.1798 (6.97)	0.1461 (8.09)	—	10	7
DM	0.2668 (8.63)	0.0995 (4.25)	−0.1934 (−8.45)	−0.1965 (−7.53)	0.4009 (6.11)	0.3052 (8.04)	—	10	5
JY	0.2756 (11.01)	0.0637 (2.74)	−0.1626 (−8.34)	−0.2039 (−7.65)	0.3864 (5.74)	0.1797 (5.88)	—	1	3
PS	0.2341 (7.32)	0.1469 (5.87)	−0.2131 (−9.43)	−0.2609 (−10.89)	0.5379 (6.79)	0.3291 (8.09)	—	1	7
SF	0.3532 (9.70)	0.0970 (3.77)	−0.2224 (−8.77)	−0.2887 (−9.81)	0.5096 (6.57)	0.2284 (5.62)	—	1	5
ED	0.0211 (3.98)	0.0035 (0.77)	−0.0098 (−1.49)	−0.0324 (−4.42)	0.0668 (6.05)	0.0433 (4.54)	5	5	5
TB	0.0118 (2.29)	0.0063 (1.67)	−0.0104 (−2.13)	−0.0248 (−6.17)	0.0398 (4.41)	0.0221 (3.63)	—	10	6

Note: A comparison of the volatility patterns among four volume/depth groups: low volume/low depth (LL), low volume/high depth (LH), high volume/low depth (HL), and high volume/high depth (HH). The volatility of returns was regressed on the four volume/depth dummies along with Monday (*M*) and 15 volatility lags; where $|\varepsilon_{it}|$ is the absolute residual from Equation 1, Q_{it} represents the *i*th quartile dummy variables for the four volume/depth combinations. The numbers in parentheses are *t* values. the *F*-test columns present the level of significance. The lag (ε) column denotes the number of the 15 lags that were significant at the 5% level or higher. See Table I for the definitions of the abbreviations.

TABLE IV

Standard Deviations of Trading-Period and Nontrading-Period Returns (× 100)

	Panel A: Low Volume/Low Depth			*Panel B: High Volume/Low Depth*	
	Trading Returns	*Nontrading Returns*		*Trading Returns*	*Nontrading Returns*
CD	0.1103	0.1429	CD	0.2984	0.3623
DM	0.2706	0.4396	DM	0.9665	0.6365
JY	0.2394	0.3349	JY	0.8785	0.4834
PS	0.3273	0.3803	PS	1.0777	0.8544
SF	0.3206	0.4837	SF	1.0419	0.8508
ED	0.0503	0.1087	ED	0.1558	0.1114
TB	0.0626	0.0776	TB	0.1098	0.0802
	Panel C: Low Volume/High Depth			*Panel D: High Volume/High Depth*	
	Trading Returns	*Nontrading Returns*		*Trading Returns*	*Nontrading Returns*
CD	0.1147	0.0858	CD	0.3562	0.2575
DM	0.3344	0.2866	DM	0.8105	0.6502
JY	0.2308	0.2745	JY	0.6100	0.6662
PS	0.2662	0.2647	PS	0.8047	0.6789
SF	0.3356	0.3308	SF	0.8698	0.6592
ED	0.0667	0.0352	ED	0.1691	0.1544
TB	0.0463	0.0328	TB	0.1325	0.1123

Trading-period (open–close) and nontrading-period (close–open) returns were grouped into four volume–depth combinations: low volume/low depth, low volume/high depth, high volume/low depth, and high volume/high depth before the standard deviations were computed. The sample spanned the period June 1982 to March 1994. See Table I for the definitions of the abbreviations.

hours of the U.S. futures market may contain a potentially significant flow of information from offshore sources. We examined the volatility patterns of trading-period and nontrading-period returns to assess the relative impact of information from domestic and offshore sources. This approach provided a way to clearly interpret test results related to information flows between trading and nontrading periods.

We first performed a simple statistical analysis of the trading-hour and nontrading-hour-return series. Table IV presents summary statistics for volatility measures of the trading and nontrading returns that coincide with the four volume–depth combinations described earlier.[14] Unlike the authors of earlier studies, we found the standard deviation of nontrading returns exceeding that of trading-period returns when market conditions contained low volume and low depth. Additionally, the trading-return vol-

[14]A warning concerning Table IV is in order: The statistics may be biased because the computation of the standard deviation does not reflect adjustments for pricing errors in the returns and autocorrelation in their variances.

atility exceeded the volatility of nontrading returns in the other volume–depth subsamples, a pattern consistent with French and Roll (1986) and Lin et al. (1994). To correct for any bias in the simple standard deviation calculation, we used the two-pass method, beginning with Equation 1, to adjust for the mean and variance autocorrelation in the analysis of return volatilities.

Estimation for the Trading-Hour and Nontrading-Hour Volatilities

In this section, we present a more rigorous analysis of the relationship between return volatility, volume, and depth for the trading-return and nontrading-return series. Tests were constructed to identify differences between nontrading-return and trading-return volatilities under the four market conditions. We implemented the two-stage testing methodology with Equation 1 and used the combined, time-sequenced $|\varepsilon_{it}|$ series of trading and nontrading volatilities as the dependent variable in the second-pass regression. We rescaled the $|\varepsilon_{it}|$ series to reflect hourly volatility of the corresponding returns.[15] We then pooled these trading and nontrading volatilities together for each of the four market conditions to observe the respective volume–depth interactions within the following equation:

$$|\varepsilon_{it}| = \alpha_i + \alpha_{im}M_t + \beta_1 Q_t D_{it} + \beta_2 Q_t N_{it} + \sum_{j=1}^{20} \rho_{ij}|\varepsilon_{it-j}| + \eta_{it} \quad (4)$$

where M_t is the Monday trading gap dummy variable that is equal to 1 for Mondays and 0 otherwise and Q_t is the quartile dummy variable for one of the four volume–depth market structures (e.g., low volume/low depth). We estimated Equation 4 separately for each of the four volume–depth combinations as specified by Q_t, where Q_t is $\{1,2,3,4\}$. The variable D_t is the trading-hour-return dummy variable at time t, where D_t is $\{0,1\}$, and N_t is the nontrading-hour-return dummy variable at time t, where N_t is $\{0,1\}$. The ρ_{it} coefficients measure the autocorrelation in the volatility of asset i.[16]

[15] We reversed the day–night sequencing and achieved identical test results.

[16] In this analysis, we report 20 lags. Because the pooled data consist of trading and nontrading returns, 20 lags imply 10 trading lags, less than the 15 trading lags reported in the analysis in the Volatility Behavior and Its Relation With Volume and Market Depth section. As shown in Table II, the coefficients of the higher lagged volatilities were insignificant. We thus used a smaller number of lags in this analysis. We experimented with more lags and obtained similar results.

We used the trading and nontrading dummy variables to isolate the effects of the four volume–depth groups in a time-series framework. Equation 4 enabled us to test whether the trading volatility coefficient (β_1) was equal to the nontrading volatility coefficient (β_2) within each of the four volume–depth market structures, where the null hypothesis (H_0) would be $\beta_1 = \beta_2$. Additionally, the hourly volatility series, $|\varepsilon_{it}|$, in Equation 4 allowed us to directly compare relative differences in volatility for the return measures.

Empirical Evidence of Volatilities between Trading Hours and Nontrading Hours

We observed that trading and nontrading volatilities exhibited distinct behaviors when exposed to different combinations of volume and depth. Panels A through D of Table V present the regression results from Equation 4.[17] We found greater volatility for nontrading returns than trading returns in markets with low volume, regardless of market depth. Panels A and C show that in the low-volume groups, the coefficients for the nontrading-return dummy variables (β_1) were significantly greater (less negative) than the coefficients for the trading-return variable (β_2) for all futures markets.[18] The results from the low-volume subgroups are similar to those reported in Table IV and reveal that the volatility of nontrading-period returns became greater than trading-period volatility in a market structure with low volume.[19] Conversely, trading-return volatility exceeded nontrading-return volatility within the high-volume groups. These results can be seen in Panels B and D, where the coefficient for the trading-return dummy exceeds that of the nontrading variable for all futures markets. Our results from the high-volume groups support the earlier observations of French and Roll (1986) and Lin et al. (1994), who documented greater return volatility during trading periods than during nontrading periods. Importantly, these test results also provide strong suggestions on how the markets use domestic and offshore information in the price-formation process.

Domestic information, usually released during the trading hours of the futures markets, should be largely responsible for the volatility of

[17]We experimented with different numbers of lags in the first-pass and second-pass tests, and the results were similar to the reported results.

[18]F tests indicated statistically significant differences between β_1 and β_2 for all futures markets in the four volume–depth subgroups.

[19]The differences between Table V and Table IV might have resulted from more rigorous testing. Table V incorporates the autocorrelation and heteroscedasticity structure in the residuals in the analysis of the return volatility.

TABLE V

Interaction of Trading-Return and Nontrading-Return Volatility with Volume–Depth Combinations ($\times 100$)

$$|\varepsilon_{it}| = \alpha_i + \alpha_{im}M_t + \beta_1 Q_t D_{it} + \beta_2 Q_t N_{it} + \sum_{j=1}^{20} \rho_{ij}|\varepsilon_{it-j}| + \eta_{it}$$

Panel A: Low Volume/Low Depth

	Constant	Monday	Trading Return	Nontrading Return	Lag (ε)	F Test, $\beta_1 = \beta_2$
CD	0.0067 (12.18)	−0.0023 (−4.35)	−0.0072 (−9.22)	−0.0029 (−6.65)	15	5
DM	0.0234 (12.73)	−0.0061 (−4.68)	−0.0251 (−12.67)	−0.0069 (−6.67)	17	1
JY	0.0189 (13.02)	−0.0077 (−6.49)	−0.0159 (−9.55)	−0.0081 (−9.30)	16	10
PS	0.0181 (10.04)	−0.0053 (−3.86)	−0.0202 (−8.45)	−0.0078 (−8.24)	15	5
SF	0.0282 (12.51)	−0.0076 (−5.08)	−0.0278 (−12.09)	−0.0071 (−5.60)	19	1
ED	0.0020 (7.33)	−0.0014 (−5.41)	−0.0031 (−8.14)	−0.0008 (−2.59)	12	1
TB	0.0013 (4.63)	−0.0008 (−3.55)	−0.0020 (−4.28)	−0.0005 (−1.73)	11	10

Panel B: High Volume/Low Depth

	Constant	Monday	Trading Return	Nontrading Return	Lag (ε)	F Test, $\beta_1 = \beta_2$
CD	0.0056 (10.43)	−0.0025 (−4.69)	0.0131 (5.45)	0.0029 (2.79)	14	—
DM	0.0198 (10.94)	−0.0062 (−4.77)	0.0555 (6.80)	0.0006 (0.34)	15	10
JY	0.0159 (11.63)	−0.0079 (−6.67)	0.0544 (6.20)	0.0002 (0.14)	16	—
PS	0.0155 (8.72)	−0.0052 (−3.79)	0.0610 (6.51)	0.0053 (2.35)	15	10
SF	0.0242 (11.07)	−0.0078 (−5.26)	0.0577 (6.52)	0.0008 (0.41)	17	1
ED	0.0017 (6.18)	−0.0014 (−5.51)	0.0094 (6.91)	−0.0001 (−0.23)	12	—
TB	0.0011 (3.93)	−0.0008 (−3.50)	0.0041 (3.64)	−0.0001 (−0.18)	10	—

Panel C: Low Volume/High Depth

	Constant	Monday	Trading Return	Nontrading Return	Lag (ε)	F Test, $\beta_1 = \beta_2$
CD	0.0062 (11.50)	−0.0023 (−4.22)	−0.0086 (−6.99)	−0.0038 (−10.22)	15	1
DM	0.0220 (12.00)	−0.0064 (−4.82)	−0.0207 (−7.04)	−0.0073 (−6.49)	17	1
JY	0.0173 (12.27)	−0.0078 (−6.54)	−0.0169 (−6.45)	−0.0089 (−7.49)	17	1
PS	0.0177 (9.73)	−0.0055 (−3.99)	−0.0231 (−8.69)	−0.0088 (−7.40)	15	1
SF	0.0262 (11.81)	−0.0076 (−5.04)	−0.0295 (−8.16)	−0.0077 (−6.11)	18	1
ED	0.0019 (6.86)	−0.0015 (−5.70)	−0.0030 (−3.53)	−0.0012 (−5.22)	12	1
TB	0.0013 (4.54)	−0.0008 (−3.40)	−0.0022 (−4.36)	−0.0010 (−5.95)	10	1

Panel D: High Volume/High Depth

	Constant	Monday	Trading Return	Nontrading Return	Lag (ε)	F Test, $\beta_1 = \beta_2$
CD	0.0058 (11.01)	−0.0023 (−4.30)	0.0157 (7.65)	0.0016 (2.78)	13	1
DM	0.0200 (11.12)	−0.0064 (−4.87)	0.0359 (7.69)	0.0054 (4.20)	16	1
JY	0.0162 (11.76)	−0.0078 (−6.58)	0.0219 (6.51)	0.0043 (3.33)	16	1
PS	0.0156 (8.71)	−0.0056 (−4.07)	0.0303 (6.45)	0.0052 (3.60)	15	1
SF	0.0244 (11.17)	−0.0075 (−5.01)	0.0372 (7.61)	0.0037 (2.60)	17	1
ED	0.0019 (6.96)	−0.0015 (−5.80)	0.0055 (5.97)	0.0000 (0.01)	11	1
TB	0.0010 (3.45)	−0.0008 (−3.43)	0.0038 (5.56)	−0.0001 (−0.49)	9	1

Note: We used the combined time-sequenced $|\varepsilon_{it}|$ series of trading and nontrading hourly volatilities as the dependent variable, where M_t is the Monday trading gap dummy variable equal to 1 for Monday and 0 otherwise and Q_t is the quartile dummy variable for one of the four volume–depth combinations (e.g., low volume/low depth). Variable D_t is the trading-return dummy variable at time t, and N_t is the nontrading-return dummy variable at time t. The ρ_{it} coefficients measure the autocorrelation in the volatility of asset i. The numbers in parentheses are t values. the F-test columns present the level of significance. The lag (ε) column denotes the number of the 20 lags that were significant at the 5% level or higher. See Table I for the definitions of the abbreviations.

trading-period returns. Yet offshore information would have a relatively greater impact on return volatility when the U.S. futures markets are closed. It would be during these nontrading hours that offshore information from the foreign spot markets would subsequently impact the futures markets. The test results in Table V reveal a consistent pattern in which the return volatility of nontrading periods exceeded the volatility of trading periods during low-volume periods. These results suggest that the U.S. market places greater emphasis on offshore information when there is a reduced flow of domestic information to the market, signified by a lower level of trading (Panels A and C). Furthermore, the greater volatility in trading-period returns when high trading volume existed (Panels B and D) may reflect a proportionally greater flow of domestic information. The same pattern is also found in the signs of the trading (β_1) and nontrading (β_2) return coefficients in Table V: They are negative for the low-volume groups (Panels A and C) and positive for the high-volume groups (Panels B and D). Thus, a positive relation existed between the trading volume and the return volatilities within trading and nontrading periods (see Karpoff, 1987; Lamoureux & Lastrapes, 1990). Because the differences in return volatility appeared to be independent of depth, these findings further suggest that trading volume dominates the effects of market depth on volatility.

We observed differences in magnitude between the volatilities of trading and nontrading returns within the high-volume and low-volume market structures. *F* tests confirmed that the coefficients for trading-return volatility and nontrading-return volatility were statistically different for all futures markets. Furthermore, we observed a greater difference during high-volume periods. When volume was high, the coefficients for the trading-period returns were 5 to 12 times greater than the significant nontrading-return coefficients. Yet in the low-volume groups, the dummy coefficients for the nontrading returns were roughly 2 to 4 times greater than the coefficients for the trading returns. Interestingly, these results suggest that offshore information has a smaller differential impact on return volatility when it dominates the market than domestic news when it is the primary information provider to the market.

The results in Table V also indicate that market depth did not play a significant role in affecting return volatility when trading and nontrading series were examined. This evidence may appear somewhat contrary to our earlier tests that showed market depth playing a statistically significant, although somewhat marginal, role in affecting return volatility.[20]

[20]See Table III, Panels A and B.

Empirical testing of Equation 4 merged the trading-return and nontrading-return volatilities and, in effect, combined domestic and offshore flows of information. The sizes and signs of the depth coefficients in Panels A through D of Table V show that market depth did not clearly differentiate between trading and nontrading volatilities. As a result, these results provide evidence for the dominance of information in trading volume over market depth in determining the volatility behavior for trading-period and nontrading-period returns.

We conducted additional tests to determine whether volume alone could explain the volatility behavior of trading and nontrading returns. In this test, we identified only high-volume and low-volume markets. The estimation of volatilities was calculated as follows:

$$|\varepsilon_{it}| = \alpha_i + \alpha_{im}M_t + \beta_1 Q_t D_{it} + \beta_2 Q_t N_{it} + \sum_{j=1}^{20} \rho_{ij}|\varepsilon_{it-j}| + \eta_{it} \quad (4a)$$

where all variables used in Equation 4a remain unchanged except for the market structure variable Q_t; it became the quartile dummy variable for low and high trading volumes.

Table VI reports the regression results from Equation 4a. In the low-volume subsample, Panel A, nontrading volatility was greater than the volatility of trading-period returns, a result similar to the results shown in Table V, and this pattern held across all futures contracts. Additionally, the test results for the high-volume subsample in Panel B show that the trading volatility exceeded nontrading volatility for all futures contracts. These results indicate that volume played a dominant role in characterizing return volatility in trading and nontrading periods. We conducted F tests and found statistical differences between all coefficients of trading-return dummies (β_1) and nontrading-return dummy variables (β_2) for all futures markets in the high-volume and low-volume samples. Additionally, the differences in magnitude between the trading-return and nontrading-return coefficients in Panels A and B were consistent with those presented in Table V. These results further demonstrate that trading volume dominates market depth in affecting the behavior of return volatilities from nontrading and trading periods.

IMPACT OF NONTRADING-PERIOD AND TRADING-PERIOD INFORMATION FLOWS OVER TIME

The globalization of financial markets and enhanced financial communication may change how the markets use domestic and offshore infor-

TABLE VI

Interaction between Trading and Nontrading-Returns and Volume ($\times 100$)

$$|\varepsilon_{it}| = \alpha_i + \alpha_{im}M_t + \beta_1 Q_t D_{it} + \beta_2 Q_t N_{it} + \sum_{j=1}^{20} \rho_{ij}|\varepsilon_{it-j}| + \eta_{it}$$

Panel A: Low Volume

	Constant	*Monday*	*Trading Return*	*Nontrading Return*	*Lag* (ε)	*F Test,* $\beta_1 = \beta_2$
CD	0.0088 (15.24)	−0.0019 (−3.48)	−0.0090 (−15.66)	−0.0046 (−15.20)	16	1
DM	0.0302 (15.96)	−0.0044 (−3.39)	−0.0305 (−19.31)	−0.0109 (−14.27)	18	1
JY	0.0248 (16.32)	−0.0068 (−5.79)	−0.0226 (−17.49)	−0.0120 (−16.77)	18	1
PS	0.0237 (12.81)	−0.0040 (−2.94)	−0.0284 (−16.84)	−0.0115 (−14.90)	16	1
SF	0.0348 (15.13)	−0.0050 (−3.37)	−0.0330 (−17.69)	−0.0111 (−12.51)	19	1
ED	0.0027 (9.30)	−0.0009 (−3.38)	−0.0039 (−14.17)	−0.0016 (−7.68)	12	1
TB	0.0018 (5.87)	−0.0006 (−2.70)	−0.0029 (−10.26)	−0.0010 (−4.82)	11	1

Panel B: High Volume

	Constant	*Monday*	*Trading Return*	*Nontrading Return*	*Lag* (ε)	*F Test,* $\beta_1 = \beta_2$
CD	0.0043 (8.37)	−0.0022 (−4.38)	0.0188 (16.18)	0.0021 (5.38)	11	1
DM	0.0169 (9.98)	−0.0050 (−3.99)	0.0523 (18.16)	0.0059 (6.91)	14	1
JY	0.0141 (10.80)	−0.0061 (−5.48)	0.0445 (15.98)	0.0086 (8.87)	11	1
PS	0.0100 (5.73)	−0.0047 (−3.54)	0.0502 (16.50)	0.0061 (6.63)	10	1
SF	0.0216 (10.46)	−0.0054 (−3.81)	0.0570 (17.79)	0.0050 (5.34)	13	1
ED	0.0011 (4.31)	−0.0009 (−3.58)	0.0088 (16.10)	0.0002 (0.77)	10	1
TB	0.0005 (1.64)	−0.0006 (−2.79)	0.0053 (12.26)	−0.0001 (−0.35)	9	1

Note: We used the combined time-sequenced $|\varepsilon_{it}|$ series of trading and nontrading hourly volatilities as the dependent variable, where M_t is the Monday trading gap dummy variable equal to 1 for Mondays and 0 otherwise and Q_t is the quartile dummy variable for low-volume and high-volume quartiles. Variable D_t is the trading-return dummy variable at time t, and N_t is the nontrading-return dummy variable at time t. The ρ_{it} coefficients measure the autocorrelation in the volatility of asset i. The numbers in parentheses are t values. The standard errors were corrected for heteroscedasticity and autocorrelation. The F-test columns present the level of significance. The lag (ε) column denotes the number of the 20 lags that were significant at the 5% level or higher. See Table I for the definitions of the abbreviations.

mation. In a market characterized by low (or high) trading volume, our earlier tests revealed that information arriving when markets are closed appears to be more (or less) significant than information arriving during the trading hours of the market. We examined the relationships across time between trading-return and nontrading-return volatilities to volume to detect changes in volatility behavior. Variations in return volatility patterns may reveal changes in the market's use of domestic and offshore information in the pricing mechanism.

We used the two-pass procedure that begins with Equation 1 and examined the relationship between trading-return and nontrading-return volatility and trading volume. We modified the test using Equation 4a by dividing our sample into two equal subperiods. In our second pass, we estimated the following regression equation:

$$|\varepsilon_{it}| = \alpha_i + \alpha_{im}M_t + \sum_{j=1}^{2} (\beta_{Nj}Q_tT_jN_{it} + \beta_{Dj}Q_tT_jD_{it}) + \sum_{j=1}^{20} \rho_{ij}|\varepsilon_{it-j}| + \eta_{it} \qquad (5)$$

where M_t is the Monday trading gap dummy variable that is 1 for Mondays and 0 otherwise and Q_t is the quartile dummy variable for either the low-volume or high-volume group. The variable N_t is the nontrading-return dummy variable at time t, and D_t is the trading-return dummy variable at time t. T_j is a (1, 0) time dummy variable for the subperiods ($j = 1$ or 2). The ρ_{it} coefficients measure the autocorrelation in the return volatility.

Panels A and B of Table VII report the patterns in return volatility across subperiods in low-volume and high-volume groups. Panel A shows that in a low-volume market structure, the nontrading volatility was larger than the trading volatility (i.e., $\beta_N > \beta_D$) for all futures contracts, with the trading-return and nontrading-return dummy coefficients remaining negative in both subperiods. Additionally, the nontrading coefficient became larger (less negative) in the second subperiod, whereas the trading coefficient became smaller (more negative).[21] The change in coefficient sizes across subperiods may reflect the increased reliance of the market on nontrading-period (offshore) information in a market structure with low trading volume because this market structure may have a relatively smaller flow of domestic information during the hours of trading.

The apparent shift toward offshore information in a low-volume market structure appears to be mirrored by an increased reliance on domestic

[21] F tests confirmed that the differences between time periods in the trading and nontrading dummy coefficients were statistically significant.

TABLE VII

Return Volatilities in Low-Volume and High-Volume Periods across Time ($\times 100$)

$$|\varepsilon_{it}| = \alpha_i + \alpha_{im}M_t + \sum_{j=1}^{2} (\beta_{Nj}Q_tT_jN_{it} + \beta_{Dj}Q_tT_jD_{it}) + \sum_{j=1}^{20} \rho_{ij}|\varepsilon_{it-j}| + \eta_{it}$$

Panel A: Low-Volume Subsample

	Constant	Monday	Period 1 Trading (T)	Period 1 Nontrading (N)	Period 2 Trading (T)	Period 2 Nontrading (N)	Lag (ε)	Period 1 F Test, $T_1 = N_1$	Period 2 F Test, $T_2 = N_2$	Period 1 Spread (T − N)	Period 2 Spread (T − N)
CD	0.0087 (14.91)	−0.0018 (−3.45)	−0.0079 (−12.93)	−0.0049 (−14.45)	−0.0106 (−12.76)	−0.0040 (−10.48)	16	5	1	0.0030	0.0065
DM	0.0303 (15.86)	−0.0044 (−3.40)	−0.0292 (−17.12)	−0.0128 (−13.33)	−0.0322 (−14.94)	−0.0085 (−10.41)	18	5	1	0.0164	0.0237
JY	0.0248 (16.10)	−0.0068 (−5.79)	−0.0210 (−14.91)	−0.0133 (−14.74)	−0.0244 (−14.45)	−0.0106 (−13.89)	18	—	1	0.0077	0.0138
PS	0.0235 (12.72)	−0.0039 (−2.87)	−0.0241 (−12.42)	−0.0129 (−14.16)	−0.0339 (−15.65)	−0.0097 (−11.03)	16	10	1	0.0112	0.0242
SF	0.0346 (14.96)	−0.0050 (−3.36)	−0.0297 (−14.64)	−0.0126 (−10.68)	−0.0367 (−14.38)	−0.0093 (−10.02)	19	5	1	0.0172	0.0274
ED	0.0028 (9.24)	−0.0009 (−3.35)	−0.0035 (−7.30)	−0.0014 (−5.64)	−0.0042 (−16.56)	−0.0017 (−7.32)	12	5	1	0.0020	0.0025
TB	0.0018 (5.89)	−0.0006 (−2.70)	−0.0028 (−6.43)	−0.0008 (−2.67)	−0.0030 (−11.40)	−0.0011 (−5.56)	11	1	1	0.0020	0.0019

Panel B: High-Volume Subsample

	Constant	Monday	Period 1 Trading (T)	Period 1 Nontrading (N)	Period 2 Trading (T)	Period 2 Nontrading (N)	Lag (ε)	Period 1 F Test, $T_1 = N_1$	Period 2 F Test, $T_2 = N_2$	Period 1 Spread (T − N)	Period 2 Spread (T − N)
CD	0.0045 (9.01)	−0.0022 (−4.50)	0.0137 (10.11)	0.0017 (3.50)	0.0259 (13.57)	0.0026 (4.48)	11	1	1	0.0120	0.0233
DM	0.0170 (10.15)	−0.0050 (−3.99)	0.0406 (10.50)	0.0072 (5.81)	0.0652 (16.03)	0.0039 (3.78)	13	1	1	0.0334	0.0613
JY	0.0143 (10.97)	−0.0059 (−5.34)	0.0348 (11.02)	0.0091 (7.42)	0.0589 (12.15)	0.0072 (5.25)	10	1	1	0.0257	0.0517
PS	0.0100 (5.71)	−0.0045 (−3.39)	0.0394 (10.96)	0.0074 (5.86)	0.0648 (12.90)	0.0041 (3.64)	10	1	1	0.0320	0.0607
SF	0.0218 (10.69)	−0.0052 (−3.76)	0.0440 (11.24)	0.0066 (5.09)	0.0746 (14.99)	0.0022 (1.93)	13	1	1	0.0375	0.0724
ED	0.0011 (4.43)	−0.0009 (−3.60)	0.0087 (11.53)	0.0007 (1.74)	0.0090 (11.78)	−0.0004 (−1.59)	10	1	1	0.0079	0.0094
TB	0.0005 (1.93)	−0.0006 (−2.77)	0.0064 (9.14)	0.0001 (0.45)	0.0045 (8.75)	−0.0002 (−1.43)	9	1	1	0.0062	0.0047

Note: Pooled return volatilities from trading and nontrading periods were regressed on two dummy variables denoting the first and second halves of the sample period conditioned on either on low-volume or high-volume groups. The spread was the difference between the day and night dummy coefficients for the first and second periods. M_t is the Monday trading gap dummy variable, and Q_t is the quartile dummy variable for low-volume and high-volume quartiles. the numbers in parentheses are t values. the F-test columns present the level of significance. The lag (ε) column denotes the number of the 20 lags that were significant at the 5% level. See Table I for the definitions of the abbreviations.

information in a high-volume environment. Panel B of Table VII presents the test results for a high-volume market structure, and we observed that the trading coefficients became larger across time, whereas the nontrading coefficients decreased in magnitude.[22] F tests confirmed the statistical significance of the changes (spread) in the trading-return and nontrading-return coefficients across subperiods. We argue that when the U.S. market experiences high trading volume, the market places greater emphasis on the flow of domestic information and a correspondingly smaller emphasis on offshore information. This pattern of information usage may explain why, in the high-volume environment, trading-return volatility increased in the second subperiod but nontrading volatility declined.

The results in Table VII suggest that the market seeks information wherever it exists and places greater importance on nontrading-period (offshore) news when trading volume is low, implying a smaller flow of domestic information. Additionally, the market appears to have increased its reliance on trading-period (domestic) information during high-volume periods, suggesting the presence of an increased flow of domestic information. These findings provide additional evidence of the global linkages that exist among financial markets and the increasing financial integration between the United States and foreign markets.[23]

CONCLUSION

In this study, we examined the effects of trading volume and market depth on the volatility of returns from trading and nontrading periods. We found that the negative impact of depth on volatility is relatively marginal and is dependent on its interaction with trading volume. Our tests revealed that market depth has a relatively greater impact on return volatility during periods with high trading volume, although trading volume exhibits greater influence on volatility across all market conditions.

We found striking evidence that the volatility of nontrading-period returns exceeds the volatility of trading-period returns in market structures characterized by low volume. This finding suggests that nontrading-

[22]The Canadian dollar futures remained the sole exception.

[23]It can be argued that there has been more volume trading in the spot market in recent years, so more information was released during the later part of the sample. In this case, our results are not necessarily related to financial market integration. However, it should be noted that trading volume in the spot exchange market after 1992 experienced a 20% reduction from a daily trading of $1 trillion to about $800 million (see *Financial Times*, June 6, 1995). Thus, the evidence does not appear to support the claim that there was more volume and, therefore, more information during the latter part of our sample.

period information dominates trading-period information in its impact on return volatility when trading volume is low. Conversely, we observed greater volatility for trading-period returns when volume is high, suggesting that high volume facilitates the flow of trading-period information that dominates nontrading-period information in the impact on return volatility. These findings imply that the U.S. market shifts its reliance for information between domestic and offshore sources, depending on the relative flow of information that exists from these sources. These test results proved to be robust across time, in different economic conditions, and with different measures of return volatility.

The results of this study provides evidence of a trend toward greater integration among financial markets. Over time, the U.S. domestic market appears to have increased its reliance on information released in nontrading periods during low-volume market structures. At the same time, however, the U.S. market seems to be placing greater emphasis on trading-period information when the market structure is characterized by high trading volume, a period when the flow of domestic information may be greater. The results of the documented relation between return volatility and market structures suggest that the futures markets have increased their global linkage in recent years as the U.S. market increasingly supplements domestic information with foreign information in the price formation of financial assets.

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