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PRICE VOLATILITY AND VOLUME SPILLOVERS BETWEEN THE TOKYO AND NEW YORK STOCK MARKETS

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ABSTRACT

This paper presents a comprehensive study of the interactions among returns, volatility, and trading volume between the U.S. and Japanese stock markets by using intradaily data from October 1985 to December 1991. By examining the effect of foreign price volatility and trading volume on correlations between foreign and domestic stock returns, the paper aims to distinguish between the market contagion and informational efficiency hypotheses in order to explain the cause of international transmission of stock returns and volatility. Major findings are three-fold: (1) contemporaneous correlations of stock returns across these two markets are significant and tend to increase during a high volatility period, which support the informational efficiency hypothesis; (2) lagged volatility and volume spillovers are not found across the two markets; (3) the effect of the New York stock returns on the Tokyo returns exhibits a structural change in October 1987.

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1. Introduction

Since the stock market crash of October 1987 there has been substantial interest in research on why stock returns and volatility are propagated across world markets. One possible interpretation for such interdependence of stock returns and volatility is an informational link across markets: news revealed in one country is perceived as informative to fundamentals of stock prices in another country.[1] This view can be attributed to real and financial linkage of economies.[2] Another possible interpretation for this issue is market contagion: stock prices in one country are affected by changes in another country beyond what is conceivable by connections through economic fundamentals. According to this view, overreaction, speculation, and/or noise trading (e.g., Delong, Shleifer, Summers, and Waldman (1990)) are transmissible across borders.

This paper studies the interdependent relationship between the Tokyo and New York stock markets by focusing on interactions of intradaily returns, volatility, and trading volume from October 1985 to December 1991. The principal objective of this paper is to disentangle the two possible interpretations by using the following three approaches. First, unlike other papers which analyzes only price changes and volatility, this paper examines the effect of trading volume on intermarket dependence in stock returns. Second, unlike several papers which study a causal relationship between price volatility and trading volume using one (domestic) market (usually the New York market), this paper is an international extension of volatility and volume studies. Third, unlike many academic and journalistic papers on the world-wide transmission of the price declines after Black Monday of 1987 in New York, this paper attempts to extend the literature of crashes by encompassing different episodes in the international transmission of large shocks in prices and volume, including the periods before and after Black Monday and the periods of the forming and bursting of the bubble of the Tokyo market.

The focus on trading volume in this paper is owing to the view that trading volume is a good proxy for the degree of heterogeneity in investors' opinions and beliefs. (See the model built by Epps and Epps (1976) and Tauchen and Pitt (1983).) Most studies have reported a positive relationship between volatility and trading volume in the (domestic) stock market (see Karpoff (1987) for an excellent survey and Gallant, Rossi, and Tauchen (1992) for the empirical regularities). According to the mixture-of-distribution hypothesis, this positive relation is often attributed to the rate of information which drives both volatility and volume.

Another line of research on the price and volume relationship (in the domestic market) attempts to explain why correlations in stock returns depend on volume and price volatility. Morse (1980) found a positive effect of trading volume on the degree of autocorrelations in domestic stock returns. He interpreted this evidence as traders' revisions of prior beliefs of shocks. (See also Harris and Raviv (1991) for a theoretical model.) By contrast, Campbell, Grossman, and Wang (1993) uncovered a negative effect of trading volume on the autocorrelation of stock returns. They associated this phenomenon with the increased expected returns that compensate for informed traders' accommodation of liquidity traders' sales, which induce higher trading volume.

This paper extends these two views of autocorrelations of stock returns to an international context. In particular, the following two hypotheses for explaining the cause of international transmission of stock returns and volatility will be examined. First, if correlations between international stock returns are caused by international contagion of liquidity traders' sentiments or by resolution of heterogenous interpretations of foreign news, such correlations will be positively influenced by foreign trading volume. We call this the market contagion hypothesis. Second, if international return correlations are associated with the informativeness of stock price changes in one market to another market, these correlations are likely to be positively influenced by foreign price volatility, but not by foreign trading volume. For instance, the domestic traders' extraction of a global factor from the observed foreign price change (e.g., King and Wadhwani (1990), and Lin, Ito, and Engle (1993)) implies such a relation. The reason is that volatility is a better measure of the rate of information flow than volume. We call this the informational efficiency hypothesis. The use of trading volume enables us to assess the two possible channels of international transmission of international stock returns and volatility by examining the causal relation between the correlations of international stock returns, trading volume, and volatility.

To carry out the above analysis, we follow Lin, Engle, and Ito (1993) and Hamao, Masulis, and Ng (1991) in using the intradaily data of stock returns for both markets in order to clearly define the daytime and overnight returns for the two markets. Since the opening time of the Tokyo market is ahead of that of the New York market by either 14 hours or 13 hours, the daytime return in one market is a subset of the overnight return in the other market. Hence, the two daytime returns are not overlapped in real time. Unlike the daily analysis by von Furstenberg and Jeon (1989) and Eun and Shim (1989), our framework is able to identify the origination of shocks, so a clean test of how fast news from one market is transmitted to the other can be implemented. Suppose that a piece of news is revealed in the foreign market such as a trade balance or GNP announcement. This news is likely to affect the earning of domestic export or import firms. According to the informational efficiency hypothesis, the domestic market is efficient in processing the foreign information, then such foreign information is incorporated into the domestic opening price. Lagged spillovers from foreign prices, volatility, or trading volume to their domestic counterparts after the domestic market opens should not arise.[3] In other words, the opening prices should reflect overnight information relevant to the domestic country. If the domestic market is inefficient in the sense that domestic investors overreact or underreact to such information, spillovers are likely to arise, in particular, when the domestic investors attempt to revise their prior beliefs about the value of stock returns or the domestic market gropes for the equilibrium price in resolving heterogenous beliefs of traders. The dependence of volatility correlations on the dispersion of expectations about the fundamental value of asset prices is suggested in a two-period noisy rational expectations model of Shalen (1993). Tests for no spillovers of return, volatility, or volume (as in Engle, Ito, and Lin (1990), and Lin, Engle, and Ito (1993)) provide a rigorous method to test for the informational efficiency hypothesis.

One may argue that volatility spillover is not necessarily against the informational efficiency hypothesis because an informational link between two markets implies that price innovations in one market can predict the arrival of information in the other market (as predicted by Roll's (1989) model).

Similarly, volume spillover does not necessarily contradict the informational efficiency hypothesis because cross-border trading induces dissemination of information across markets. However, many studies in the literature have reported that cross-border trading is very light (Kleidon and Werner (1993)), and that the arrival rate of market-wide information is not correlated due to infrequent policy coordination and competition between Japan and the United States (see Ito, Engle, and Lin (1992) for evidence). We believe that the possibility of either dependence on the arrival of information or cross-border trading exists, but that their effect on the stock prices may be very weak.

The test for volume spillovers is also motivated by the volume behavior on Black Monday, October 19, 1987. On that day, the S&P 500 composite index plunged 22.9 percent, setting off international repercussions. On the next day, the Nikkei 225 index declined 16.1% and other world stock markets experienced similar sharp price declines. This well-known fact is still fresh in our memories. However, little attention has been paid to the volume behavior during the Crash period. The price declined on Black Monday in New York in heavy trading of 604 million shares, whereas Tokyo, the next day, traded only 618 million shares, which is rather light for the Tokyo market. As shown in Figures 1 and 2, which plot the number of shares traded before and after the crash, the New York volume remained high for several days before and after Black Monday, while there was no such volume surge in Tokyo. This extended lack of volume surge cannot be explained by the trading halts of several individual stocks in Tokyo on the day after Black Monday.[4] This phenomenon motivates us to seek an alternative way to examine the informational efficiency hypothesis by testing for no return, volatility, volume spillovers when a large foreign price (volume) shock occurs. Since price changes contain information and noise, under either one of the above two circumstances there is an increase in uncertainties in interpreting the effect of foreign price changes on the domestic stock price through connection of fundamental information. Hence, the domestic market may take more time to digest the foreign price changes. Return, volatility, or volume spillovers are likely to appear. We will take a close look at the effect of the Crash of October 19, 1987, on the international transmission of stock returns. In particular, we will use hourly data to examine whether the correlation of stock returns in the United States and Japan increased during the Crash period and whether spillovers of international stock returns, volatility, and volume are likely to prevail when a large foreign price (volume) shock occurs during the other periods.

The rest of this paper is organized as follows: Section 2 describes the empirical framework; Section 3 presents an analysis of the correlation of stock returns between the New York and Tokyo markets; Section 4 reports empirical results for the causal relationship of volatility and trading volume between New York and Tokyo; Section 5 examines the effect of the Crash on correlations between the New York and Tokyo stock markets; Section 6 concludes the paper by summarizing our main findings.

2. Model and Econometric Specification

2.1 Return Process

To analyze the international transmission of stock returns and volatility, King and Wadhwani (1990) set out a simple autoregressive and moving average process implied by a time-invariance extraction process; Hamao, Masulis, and Ng (1990) employed the GARCH-in-mean process; and Lin, Engle, and Ito (1993) used a signal extraction (Kalman filter) model with time-varying variances. This paper examines the issue along this line.

Following Lin, Engle, and Ito (1993), a daily (close-to-close) return is divided into a daytime (open-to-close) return and an overnight (close(t-1)-to-open) return for both Tokyo and New York:

$$NK_t = NKN_{t-1} + NKD_t$$

$$SP_t = SPN_t + SPD_t$$

where NK and SP denote returns for the Nikkei 225 (NK225) and Standard and Poor 500's (S&P 500) price indices, respectively, and suffixes D and N denote daytime and overnight, respectively. See Figure 3 for detailed information about the timing of the markets.[5]

< Insert Figure 3 here>

Let HR be the domestic stock return and FR be the foreign return. Allowing for possible autocorrelations from the preceding overnight return, for Monday or post-holiday effects through a dummy variable, DM, and for the influence from abroad, we can write the domestic overnight return as:[6]

$$HRN_t = a_n + b_n HRD_{t-1} + c_n DM_t + m_{n,t} FRD_t + e_{n,t} \qquad (1)$$

where $(HRN_t, HRD_{t-1}, FRD_t) \in \{(NKN_t, NKD_{t-1}, SPD_t), (SPN_t, SPD_{t-1}, NKD_t)\}$.[7] The (contemporaneous) effect of foreign information is $m_{n,t}\, FRD_t$. A shock (news) revealed after the close of the foreign market but before the opening of the domestic market is denoted as $e_{n,t}$. We also assume that the daytime return follows a process similar to that of the overnight return:

$$HRD_t = a_d + b_d HRN_t + c_d DM_t + m_{d,t} FRD_t + e_{d,t} \qquad (2)$$

where $(HRD_t, HRN_t, FRD_t) \in \{(NKD_t, NKN_{t-1}, SPD_{t-1}), (SPD_t, SPN_t, NKD_t)\}$ and $e_{d,t}$ is the unexpected part of the return. Since the information about the foreign market movement has become available to domestic investors at the open, $m_{d,t}\, HRF_t$ is the spillover effect from the foreign market to the domestic daytime returns. If the market is efficient, foreign news should be fully reflected in the opening price of the domestic market and $m_{d,t}$ will be equal to zero.

As mentioned in the above section, the objective of this analysis is to disentangle the informational efficiency vs. market contagion hypotheses for the cause of international transmission of stock returns. Therefore, we allow $m_{d,t}$ and $m_{n,t}$ to vary with dummy variables for big volume, a big shock, and the sign of price changes in the foreign market. The effect of a big shock using absolute returns as a proxy for volatility incorporates the implication of the informational efficiency hypothesis (such as predicted by the signal extraction model), whereas the effect of foreign trading volume incorporates the implication of the market contagion hypothesis. Specifically, $m_{d,t}$ (or $m_{n,t}$) follows:

$$\begin{aligned} m_{k,t} = \mu_{k,0} &+ \mu_{k,1}\, I\{FRD_t < 0\} + \mu_{k,2}\, I\{|FRD_t| > \sigma(FRD)\} \\ &+ \mu_{k,3}\, I\{FRV_t > \sigma(FRV)\}, \qquad k=n,\text{and } d \qquad (3) \end{aligned}$$

where I{A} is an indicator function whose value is equal to one if statement A is true, $\sigma(X)$ is the sample standard deviation of variable X, and FRV is the foreign trading volume after detrending and removing the day-of-week effect. For simplicity, we denote $I\{FRD_t < 0\}$ as I_n, $I\{|FRD_t| > \sigma(FRD)\}$ as I_b, and $I\{|FRV_t| > \sigma(FRV)\}$ as I_v in Tables 3 to 5.

2.2 Volatility and Volume Processes

It has long been recognized that the volatility of stock prices is time-varying and clustered (see Bollerslev, Chou, and Kroner (1992) for a survey article). To examine the cross-market dependence on trading volume and volatility, we extend the specification of the GARCH process to account for possible variations in the effect of volatility spillovers across markets and the effect of the foreign trading volume on the domestic conditional variances. The volatility processes of $e_{d,t}$ and $e_{n,t}$ follow:

$$e_{n,t} | \Omega(j) \sim N(0, h_{n,t}) \qquad j \in \{TKC_t, NYC_t\}$$

$$e_{d,t} | \Omega(j) \sim N(0, h_{d,t}) \qquad j \in \{TKO_t, NYO_t\} \qquad (4)$$

where $\Omega(j)$ denotes the information set containing domestic and foreign daytime and overnight stock returns up to time j, and N(.,.) denotes a normal distribution with the first element being the mean and the second element being the variance conditional on $\Omega(j)$. The conditional variance, $h_{d,t}$ or $h_{n,t}$, follows:

$$h_{k,t} = \omega_k + \alpha_k (e_{k,t-1})^2 + \beta_k h_{k,t-1} + \gamma_n DM_t$$
$$+ \delta_k (FRV_t)^2 + \rho_{k,t} (r_t)^2 \qquad \text{for } k = n, \text{ and } d \qquad (5)$$

In equation (5), we allow squared changes in shocks from the foreign daytime returns and trading volume (denoted as r_t and FRV_t, respectively) to influence the conditional variances of overnight returns. r_t is the unexpected part of stock returns (i.e., residuals from OLS regression), whereas FRV_t is the foreign trading volume after removal of a trend component and the day-of-week effect. This setup enables us to test for contemporaneous correlations and lagged spilloves of price volatility between the international stock markets as studied by Lin et al. (1993) and Hamao et al. (1990). A notable difference from the previous studies is that we allow the impact of the squared foreign return shock on the domestic variance to vary. Accounting for the effects of the sign of returns, a big shock, and high volume, we write $\rho_{k,t}$, for k = n and d, as:

$$\rho_{k,t} = \rho_{k,0} + \rho_{k,1}\, I\{r_t<0\} + \rho_{k,2}\, I\{|r_t|>\sigma(r)\} + \rho_{k,3}\, I\{FRV_t>\sigma(FRV)\} \quad (6)$$

The specification of $\rho_{k,t}$ is motivated by the idea of Engle et al. (1991) for intermarket dependence in volatility and of Black (1976) and Christie (1982) for the leverage effect. In particular, when a big shock (due to a large rate of information flow) or big volume (due to the increased heterogeneity in investors' beliefs or sentiments) occurs in the foreign market, it may take more time for the market to resolve heterogenous interpretations or to disseminate information. In this situation, the market is not efficient in digesting new information and lagged spillovers will occur.

It is the well-known stylized fact that trading volume and volatility are positively correlated. Lamoureux and Lastrapes (1990) found that trading volume, a proxy for information arrival time, can affect the conditional variances (contemporaneously). The interpretation of this phenomenon is along the line of the mixture-of-distribution hypothesis--the rate of information flows is a driving force for both volatility and volume. In contrast with the mixture-of- distribution hypothesis, we explore whether the trading volume, a proxy for heterogeneity in foreign investors' beliefs, has explanatory power for the conditional variance of domestic returns.

The number of shares traded is used to measure trading volume, which usually exhibits nonstationarity. Campbell, Grossman, and Wang (1993) argued that a one-year backward moving average of past volume seems to be a better measure of market making capacity. We use a similar procedure to remove the nonstationarity by obtaining the deviation from the 100-day backward moving average of past volume.[8] Trading volume strongly exhibits the day-of-week effect as reported by Jain and Joh (1988) and Gallant, Rossi, and Tauchen (1992). We also remove the day-of-week and holiday effects from the 100-day backward moving average of past volume. This daily volume variable, after removal of nonstationarity and the day-of-week and holiday effects, is denoted as HRV or FRV. To test our hypothesis of cross-market volume-price relation, we specify the volume process as

$$\begin{aligned} HRV_t = {} & \Sigma_i \pi_i\, HRV_{t-i} + \Sigma_i\, \theta_i\, FRV_{t-i} + \Sigma_i\, \phi_i\, |HRD_{t-i}| + \Sigma_i\, \lambda_i\, |FRD_{t-i}| \\ & + \phi^* I\{HRD_{t-1}<0\})\, |HRD_{t-1}| + \lambda^* I\{FRD_t<0\})\, |FRD_t| + v_t \qquad (7) \end{aligned}$$

In equation (7), like many studies in the volume and volatility relation (e.g., Jain and Joh (1988)), we use the absolute returns as a proxy for the rate of information to examine whether new information increases investors' heterogeneity and increases the incentive to trade. Unlike those studies, we allow both foreign and domestic absolute returns to affect the domestic trading volume. Similarly, the decrease in prices often suppresses the incentive to trade because of the increased in risk aversions, a short-sale constraint, or other market frictions. We also specify this effect in a cross-market framework.

3. Cross-Market Dependence of U.S. and Japanese Stock Returns

3.1. Data Summary

The Tokyo Stock Exchange (TSE) and the New York Stock Exchange (NYSE) are the two largest equity markets in the world. We adopt the Nikkei 225 and S&P 500 as the stock price indices for our analysis.[9] The NYSE opens its trading at 9:30 a.m. and continues trading until 4:00 p.m. The TSE opens at 9:00 a.m. and trades until 11:00 a.m. when it breaks for lunch. Prior to spring 1991, the afternoon session began at 1:00 p.m. and continued until 3:00 p.m. Since the spring of 1991 the afternoon session has started at 12:30 p.m. Tokyo is ahead of New York by either 14 hours (in the winter) or 13 hours (in the summer), so these trading hours do not overlap in real time.

Since we use the stock price indices, we have to worry about the problem of stale quotes in the opening of the market. As analyzed by Stoll and Whaley (1990), the average time to open a NYSE stock was 15 minutes during 1982-1988. Consequently, the opening index defined only a minute after trading begins may not reflect all the relevant information. Lin et al. (1993) reported a wide range of correlation analyses between S&P500 and NK225 daytime and overnight returns and found that 30 (15) minutes after the official opening of the New York (Tokyo) Stock Exchange is a good proxy for opening quotes which can mitigate the effect of stale quotes or nonsynchronous trading.

To analyze whether interdependence in international stock returns depend on the regimes of bull or bear markets, we divide our sample from October 1985 to December 1991 into four subperiods: the first period runs from October 1, 1985 to September 30, 1987; the second from October 1, 1987 to December 31, 1987; the third from January 1, 1988 to December 31, 1989; and the last from January 1, 1990 to December 31, 1991. The first period was a bull-market period in which the Nikkei index moved from 12685 to 26010; the second a bear-market period which experienced a crash and the Nikkei index dropped from 26010 to 21564; the third started tranquilly and then turned into a bull market in which the Nikkei index went from 21564 to 38915; and the last was a bear market period for the TSE during which the Nikkei decreased to 22983.

The data summary for overnight and daytime returns, and volume after removal of a trend component and the day-of-week and holiday effects for these four subperiods is presented in Table 1. Standard errors adjusted for heteroskedasticity and serial correlations (e.g., Newey and West (1987)) are reported in parentheses. Panel A of Table 1 shows the results for the Tokyo stock market. The stock returns became more volatile in both the Crash and the fourth periods, while trading volume decreased. The stability test for the null hypothesis of equality of mean returns and their variances is rejected. Panel B of Table 1 shows that the standard deviation of stock returns in the NYSE was higher in the Crash period, and trading volume was lower in the third and the fourth regimes. The stability test also shows a rejection of the equality of the variances of stock returns and trading volume across the four regimes.

3.2 Cross-Market Dependence

We begin by presenting evidence concerning the time-varying dependence of international stock returns. This dependence of international stock returns may result from traders' extraction of foreign news (e.g., King and Wadhwani (1990), and Lin, Engle, and Ito (1993)), which depends on price volatility. A related study by Neumark, Tinsley, and Tosini (1991) assessed the dependence of volatility on correlations of international stock returns by sorting data during several weeks of the Crash period according to high or low-volatility periods.[10] Gauging this volatility dependence hypothesis is a first step toward understanding the informational efficiency vs. market contagion hypotheses. We use the above four data periods from 1985 to 1991 covering the Crash and the bull and bear periods of the Tokyo stock market to examine whether correlations (spillovers) between international stock returns depend upon the regimes of bull and bear markets and exhibit a structural break, whether the correlations dominated during the Crash period, and whether the Crash increased the international transmission of stock returns and volatility afterwards.

Table 2 shows the estimated regression results for cross-market dependence in stock returns across the New York and Tokyo stock markets. The results are obtained by using the ordinary least squared (OLS) estimation of equations (1) and (2) and by fixing $m_{n,t}$ or $m_{d,t}$ as a constant. The coefficient m_n measures the impact of the foreign daytime return on the domestic overnight returns (i.e., the contemporaneous correlations of stock returns), while the coefficient m_d measures the impact of the foreign daytime return on the domestic daytime returns (i.e., the lagged spillover effect). Panel A presents the results for the impact of the New York daytime returns on the Tokyo daytime and overnight returns, whereas Panel B presents the results for the effect of the NK225 daytime return to the S&P500 daytime and overnight returns. White's (1980) heteroskedasticity consistent standard errors are reported in the parentheses. Several conclusions emerge from Table 2.

First, the first column in Table 2 shows the coefficient of S&P500 daytime returns (SPD) on the regression of NK225 overnight returns (NKN). The hours defining SPD are a subset of those defining NKN, as shown in Figure 3. Similarly, the third column shows the coefficient of NKD on the regression of SPN, where the hours of NKD are a subset of those of SPN. In general, the two contemporaneous effects of the foreign daytime return on the domestic overnight return, coefficient m_n, are statistically significant in all regimes when the lagged effects of the home market and various weekend and holiday effects are controlled. The second and fourth columns, using equation (2), show the estimated coefficients of (lagged) spillovers from SPD_{t-1} to NKD_t and NKD_t to SPD_t. These estimates and student t statistics show that (lagged) international spillovers are generally insignificant. Combining the results of significant contemporaneous dependence in stock returns but insignificant spillovers, we can assert that any news revealed in the foreign market overnight are completely incorporated into the opening prices of the home market as we allow some minutes to avoid a stale quote problem (see Lin, Engle, and Ito (1993) for further discussion of this issue).

Second, the contemporaneous correlation of international stock returns measured as m_{n} in equation (1) for Regime 2, the Crash period, are smaller than those for other periods, while the coefficients for the lagged spillovers of the Crash period are greater than those of other periods. A comparison of the magnitude of coefficients in Regime 2 to those in other regimes suggests that during the Crash period, news revealed in the foreign markets could not be incorporated into the opening price due to the increased uncertainty and breakdown in interpretation of large shocks. Hence, because the Crash period is so different, we will not use it in our subsequent analysis.

Third, a comparison of the magnitudes of the two coefficients for contemporaneous correlations shows both the effect of SPD on NKN and the effect of NKD on SPN. The former effect (Column 1) is greater than the latter effect (Column 3). In addition, the impact of foreign stock returns on domestic overnight stock returns increased in the fourth period but declined in the Crash period. Tests for structural breaks, given these three break points, show a rejection of the null hypothesis of no structural breaks in the Tokyo market, but not in the New York market. Finding a positive and larger coefficient for contemporaneous correlations in international stock returns may not imply the increased integration of the international financial markets. One explanation for this argument is that the correlation of the stock returns depends on the nature of the shocks. Some shocks affect the stock returns in the same direction but others affect them oppositely. Thus, the sign of the contemporaneous correlations of the international stock returns depends on the combined effects of these two types of shocks. Moreover, the evidence that the impact of SPD on NKN is larger than that of NKD on SPN does not imply that New York news is more important for the Tokyo market, because the effect of a third country is ignored in our analysis.[11]

3.3 Asymmetric Effects on Cross-Market Correlations and Spillovers

In the above analysis, we have shown that domestic overnight returns are significantly affected by foreign daytime returns. In this section, we extend our previous analysis by examining the following asymmetric effects on the international transmission of stock returns and volatility: (i) volatility effect--the cross-market dependence on stock returns (contemporaneous correlations or lagged spillovers) will be greater when the volatility increases; (ii) volume effect--the cross-market dependence on stock returns will be greater when international stock return correlations or spillovers are associated with trading volume; (iii) sign of price changes--a decline in prices, as opposed to an increase, will increase the effect of international transmission on stock returns and volatility.

In the context of the international transmission of stock returns, King and Wadhwani (1990), Lin et al. (1993), and Neumark, Tinsley, and Tosini (1991) have highlighted the importance of the increase in correlations of international stock returns during the period of high volatility. The purpose of examining the first and second effects is to disentangle the informational efficiency hypothesis from the market contagion hypothesis. As for the third effect, Nelson (1991) argued that a decline in prices is associated with higher future price variability. This asymmetry has been attributed to a leverage effect (e.g., Black (1976) and Christie (1982)) in which a decline in equity prices decreases the equity to debt ratio and increases the riskiness of the firms. From an international perspective, a leverage effect may increase domestic price volatility and hence increase the international correlation coefficient as investors extract the information from overseas price changes.

In Table 3, we present the empirical results for various asymmetric effects on cross-market dependence in stock returns, which can be viewed as an extension of correlations of stock returns in the home market (e.g., Antoniewicz (1992), Campbell et al., and LeBaron (1992)) to an international context. Our interacting variables include dummies for a negative return, a big price shock (i.e., absolute returns greater than one standard deviation of returns in the sample), and big volume. Since the Crash period spans only three months (the number of observations is less than 70), we report the results only for the other three periods in the followings and Section 4.

These empirical results are not strongly supportive of asymmetric effects on cross-market correlations. A big shock from S&P500 returns significantly increased the influence of S&P500 daytime returns on NK225 overnight returns in Regimes 1 and 3 and negative S&P500 daytime returns also increased such an impact in Regime 1. However, a big volume has no impact on the contemporaneous correlation of stock returns across markets. The results for the asymmetric effect of NK225 daytime returns on the S&P500 returns are also weak. There is no evidence of a significant effect of either Tokyo volume or price volatility on New York stock returns, which can be repeatedly shown across all three regimes.

The aim of the above analysis in Tables 2 and 3 is to shed light on the market contagion and informational efficiency hypotheses. Under the market contagion hypothesis, applying the idea of Campbell, Grossman, and Wang (1993), the informed traders in the home market would be likely to accommodate the sale of uninformed traders who, observing a price drop in the foreign market, may become more risk averse. As a result, the expected returns would increase, the current price would drop, and the effect of foreign daytime returns on domestic overnight (daytime) returns would increase (decrease) when the volume increased. Under the informational efficiency hypothesis, the foreign price changes are informative to the fundamentals of the domestic stock returns. As a result, a higher rate of information in the foreign market will increase (contemporaneous) correlations of stock returns between the home and foreign markets as investors extract this information from the observed foreign price change. Our findings of contemporaneous correlations of stock returns across markets in Tables 2 and 3 dispute the market contagion scenario. Moreover, the findings of no significant spillover from the foreign daytime return to the domestic overnight return are supportive to the informational efficiency hypothesis in that the domestic market can very quickly process the foreign information.

4. Evidence on the Volatility and Volume Processes

The cause of correlations and spillovers in volatility and volume across markets is another focus of this paper. In this section, we apply a two-stage GARCH estimation method to specify the processes of time-varying conditional variances: first, we employ an OLS regression for equations (1) and (2) and obtain OLS residuals; second, we fit a GARCH process for conditional variances of unexpected returns. After fitting the GARCH model, we calculate the skewness and the kurtosis of standardized residuals. These statistics are still too large to accept the null hypothesis of a normal distribution. Therefore, we report the robust standard errors as calculated by Bollerslev and Wooldridge (1992). The volume process is estimated by OLS with White's (1980) heteroskedasticity consistent covariance matrix.

4.1 Volatility Process

One line of research on intermarket dependence of financial markets examines volatility correlations and spillovers across markets. For instance, Engle, Ito, and Lin (1990), and Ito, Lin, and Engle (1992) investigated this issue for the foreign exchange markets. Chan, Chan, and Karolyi (1991) examined intermarket dependence across the stock index and the stock index future markets. Since volatility is related to the rate of information flows (e.g., Ross (1989)), the intermarket dependence in volatility of both markets can be attributed to dissemination of information flow between the two markets. Volatility is also partly related to the dispersion of prior beliefs (e.g., Shalen (1993)). As predicted by Shalen's (1993) model, an increase in the dispersion of beliefs may induce volatility correlations (spillovers). In this section, the test for no volatility spillovers is used to gauge the second hypothesis by examining how fast the market gropes for the equilibrium price and resolves heterogenous beliefs.

Following the procedure described in the beginning of Section 4, we report the empirical results in Table 4. A big shock or a big volume dummy interacting with the square of foreign price volatility does not have explanatory power for the domestic price volatility. Furthermore, we found that there is no causal relation between lagged foreign trading volume and domestic conditional variances. Overall, our results are consistent with Lin et al. (1993) who showed a lack of volatility correlation or spillover effects. The findings suggest that the domestic market may adjust to foreign information very quickly in resolving domestic investors' dispersion of beliefs about foreign information. Hence, there are no volatility spillovers. Some attention may be given to the asymmetric effect of the sign of the foreign price change on the volatility spillovers.

4.2. Volume Processes

Why may trading volume be correlated across markets? Several possible factors may contribute to this phenomenon. The first is cross-market trading. Chowdhry and Nanda (1991) developed a theoretical framework to explain the practice of multimarket trading. They showed that when a security trades at multiple locations simultaneously, an informed trader has several ways to exploit his private information. As the proportion of liquidity trading by large traders who can split their trades across markets increases, the correlation between volume in different markets will increase. A second factor is the increase in dispersion of beliefs about the information revealed in other markets.

Table 5 reports the estimated processes for trading volume and shows that trading volume in one market cannot significantly Granger cause trading volume in he other market. The behavior of trading volume across markets has not received great attention in the literature. French and Poterba (1990) showed that cross-border trading accounts for less than 1% of trading in the Tokyo and New York markets (Kleidon and Werner (1993) also show limited cross-border trading for the London and New York markets). Due to the limited cross-border trading, it is not surprising that there is no significant evidence of intermarket dependence on the trading volume (except in the case of the Tokyo stock market in the fourth period).

We also test whether absolute returns, used as a proxy for the arrival rate of information, will affect trading volume across markets. By evaluating Wald statistics having a chi-squared distribution with the degree of freedom of six, we find that the null hypothesis of no effect of foreign absolute returns on domestic trading volume cannot be rejected except for the effect of SPD on NKV in the first period. This result suggests that foreign information may not change domestic investors' incentive to trade. This result, along with the result of no evidence of cross-market interdependence in trading volume, suggests that the dissemination of foreign information does not increase the heterogeneity in domestic investors' beliefs about foreign news nor increase incentives to trade. These results also suggest that the market may be efficient in processing foreign news and that opening prices incorporate such overnight news.

We also examine the asymmetric effects on trading volume and report the results on the left side of Table 5. Literature has documented that volume becomes lower when returns drop than when returns rise. Studies attribute this phenomenon to the cost of short selling, borrowing, or an increase in risk aversion (see the survey by Karpoff (1987)). The results reported in the middle part of Table 5 show evidence of the asymmetric effect of returns on trading volume not only in the domestic market, but also across markets. [12]

5. Return Spillovers during the Crash Period

The stock market crash of October 19, 1987 has inspired several studies of its causes, although consensus has not yet been reached. Roll (1989) suggested downward revised expectations for world-wide economic activity, while Seyhun (1990) argued for the overreaction of uninformed traders by using positive feedback strategies. Evidence of the abnormally higher autocorrelations of high frequency (cash) stock index returns is also reported in Harris (1989) and Kleidon (1992). Harris suggested that this was due to nonsynchronous trading, whereas Kleidon (1992) argued that it was caused by stale quotes attributable to the physical limitations in the processing of automated orders on the NYSE during the crash period.

In section 3.2, we found that there is a significant increase in return spillovers from SPD to NKD. Hence, we further investigate how fast such spillovers can die out. In contrast to the analysis of correlations in domestic (cash and future) stock returns by Harris (1989) and Kleidon (1992), this analysis is an examination of cross correlations of New York and Tokyo stock returns during the Crash period. Table 6 reported an OLS regression, similar to equation (2), for hourly stock returns. The standard errors are also adjusted for heteroskedasticity. We found a significant spillover effect of SPD on NK225 hourly returns. The significant impact of SPD on hourly NK225 returns appears during all business hours in the Tokyo market except for the lunch break, while the impact of NKD on S&P500 hourly stock returns is significant only from 1 p.m. to 2 p.m. Since we did not observe abnormal trading volume in Tokyo during the Crash period, we conjecture that the Crash was informative to Tokyo traders but they became more skeptical about the causes of the Crash. Thus, uncertainties about the cause of the Crash may lead to a lag adjustment of this information and a significant return spillover.

6. Conclusion

The world scope of the stock market crash in October 1987 raised concerns about how financial disturbances transmit from one market to another. In this paper, we extend the previous work in this area (e.g., King and Wadhwani (1990), Lin et al. (1993), and Hamao et al. (1990)) by accounting for the interactions of trading volume, returns, and volatility across markets. Trading volume is used because it can serve as a proxy for the degree of heterogeneity in investors' beliefs. We approach this issue by using a simple regression model with a GARCH process and by considering the asymmetric effects of the sign and magnitude of stock returns and the magnitude of trading volume.

Using this framework, we test whether the transmission of international financial disturbances is due to liquidity traders' sentiments or to the informativeness of stock returns. On one hand, if the transmission of international financial disturbances results from the first source, as the model of Campbell, Grossman, and Wang (1993) predict, the impact of foreign daytime returns on domestic overnight (daytime) returns is likely to increase (decrease) when the volume is higher. On the other hand, if the transmission results from the second source, the correlation will increase with the volatility of shocks as domestic investors extract the foreign information, as described by King and

Wadhwani (1990) and Lin et al. (1993).

Our general finding is supportive of the second hypothesis for the transmission of shocks from the New York market to the Tokyo market. We uncovered evidence that the regression coefficient of the S&P500 daytime returns on the NK225 overnight returns increases when a big shock occurs. In addition, we found no evidence on volume, volatility, or return spillovers for four regimes except the Crash period, so opening prices, after allowing some time for clearing stale quotes, reflect all world news revealed overnight. Thus, both markets adjust foreign information efficiently.

ENDNOTES

1\. See, for example, Chan, Chan, and Karolyi (1991), Dravid, Richardson, and Craig (1993), and Lin, Engle, and Ito (1993).

2\. An international asset pricing model (e.g., Adler and Dumas (1983) and Solnik (1974)) can incorporate correlations between stock returns in different countries.

3\. In this paper, we define correlations of stock returns between the New York and Tokyo markets as the cross-correlation between the daytime returns in one market and the overnight returns in the other market, where the time span of both returns overlaps in real time. By contrast, we define spillovers of stock returns between the two markets as correlations between the daytime returns in one market and the subsequent daytime returns in the other market, where the time span of the two returns does not overlaps. A similar definition is also applied to trading volume and price volatility.

4\. On October 21, 1987, Nihon Keizai Shimbun reported:

> "The limit on price changes in a day is as follows: 50 yen for stocks with prices between 100 and 200; 80 yen for stocks with prices between 200 and 500; 100 yen for stocks between 500 and 1,000, etc.... Theoretically, if all listed stocks on the Tokyo Stock Exchange were at the bottom of the price change limit, it would be -4059.75 in the Nikkei 225 index, while the actual change on October 20 was -3,386.48. On October 20, trading occurred on 753 stocks out of 1,100 listed stocks. Of the 753 stocks, 569 were at the bottom of the price limit (translated by the authors)."

In sum, on October 20, there were many stocks which were not traded because of the price change limit. During several weeks after October 20, there was little evidence that the price limit prevented trading from taking place.

5\. According to analyses by Stoll and Whaley (1990) and Lin et al. (1993), the 9:15 quotes for the TSE and the 10:00 quotes for the NYSE are chosen to avoid the nonsynchronous trading problem.

6\. The Monday dummy for SPN is equal to one for returns from Friday close to Monday open and returns during holidays, and is equal to zero otherwise. The Monday dummy for NKN is equal to one for returns from Friday close to Monday open in the absence of Saturday trading, returns from

Saturday close to Monday open in the presence of Saturday trading, and returns during holidays, and is equal to zero otherwise. See Gibbons and Hess (1981) for the evidence on the day-of-week effect.

7. Note the time difference: Tokyo is ahead of New York by either 14 hours or 13 hours (when New York is observing daylight saving time). Hence, the past foreign daytime returns, FRD, on the right-hand-side of equation (1) should be day t-1, S&P500 in the Tokyo equation, and day t, Nikkei in the New York equation.

8. We denote the deviation of the trading volume from a 100-day backward moving average as HRMAV. To remove the day-of-week effect and holiday effect, we obtain HRV from the OLS residuals of the regression of HRMAV on several dummy variables as follows:

$$HRMAV_t = c + d_0 MON_t + d_1 TUE_t + d_2 THR_t + d_3 FRI_t + d_4 SAT_t$$
$$+ b_1\, PRH_t + b_2\, PSH_t + b_3\, CHRS_t + HRV_t$$

where MON, TUE, THR, FRI, and SAT are the dummy variables for Monday, Tuesday, Thursday, Friday, and Saturday; and PRH, PSH, and CHRS are dummy variables for the day before holidays, the day after holidays, and the Christmas season from December 20 to January 10.

9. The Standard and Poor's 500 (S&P 500) is the equity-value weighted arithmetic mean of 500 stocks selected by Standard and Poor. The hourly data for the S&P 500 are kindly provided to us by Dr. J. Harold Muherlin. The Nikkei 225 (NK225) is a price-weighted simple average of 225 stock prices selected by Nihon Keizai Shimbun.

10. They assert that when volatility is high, the cross border transaction is likely to be profitable and the correlations of international stocks will increase.

11. We thank for George von Furstenberg for this comments to us about these phenomena.

12. We also test for the asymmetric effect of a large shock and a high volume from the domestic and foreign markets on the trading volume in the domestic markets. We find insignificant results. Therefore, the results are not reported.

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Table 1: Data Summary

Panel A: Nikkei 225

	NKMAV[d]		NKN		NKD	
	mean[b]	std.	mean	std.	mean	std.
Regime 1[a]	0.175 (0.069)	0.531 (0.024)	0.181 (0.016)	0.385 (0.019)	-0.052 (0.033)	0.776 (0.056)
Regime 2	-0.422 (0.123)	0.507 (0.046)	0.078 (0.094)	0.733 (0.056)	-0.353 (0.211)	2.523 (0.820)
Regime 3	0.010 (0.053)	0.472 (0.030)	0.150 (0.015)	0.384 (0.022)	-0.037 (0.022)	0.505 (0.034)
Regime 4	-0.231 (0.046)	0.373 (0.033)	0.050 (0.032)	0.786 (0.039)	-0.157 (0.057)	1.360 (0.144)
Test[c]	34.556 (0.000)	10.910 (0.001)	13.926 (0.003)	76.627 (0.000)	5.874 (0.118)	31.500 (0.000)

Panel B: Standard and Poor 500

	SPMAV[d]		SPN		SPD	
	mean[b]	std.	mean	std.	mean	std.
Regime 1[a]	0.141 (0.020)	0.201 (0.015)	0.026 (0.021)	0.466 (0.027)	0.086 (0.034)	0.795 (0.037)
Regime 2	0.107 (0.090)	0.363 (0.073)	-0.076 (0.140)	1.831 (0.383)	-0.337 (0.388)	2.888 (0.988)
Regime 3	-0.036 (0.019)	0.211 (0.011)	0.024 (0.020)	0.446 (0.030)	0.047 (0.028)	0.826 (0.093)
Regime 4	0.020 (0.020)	0.213 (0.015)	-0.010 (0.022)	0.513 (0.046)	0.043 (0.034)	0.803 (0.034)
Test[c]	43.335 (0.000)	3.204 (0.361)	2.185 (0.535)	6.422 (0.093)	2.061 (0.560)	1.916 (0.590)

Notes:

(a) The number of observations in Panel A is 556, 64, 522, and 499; in Panel B, 506, 64, 504, and 506.

(b) The sample mean and standard deviations are reported in this Table. The standard errors computed from the Newey and West (1987) autocorrelation- and heteroskedasticity-consistent covariance matrix for the sample mean and standard deviations are reported in the parentheses.

(c) Wald test statistics are for the null hypothesis that all coefficients of Regimes 1 to 4 for the column are identical.

(d) NKMAV or SPMAV denotes the deviation of the log of trading volume from its 100-day backward moving average of past volume.

Table 2 Cross-Market Dependence in Stock Returns

OLS Regression:

$$HRN_t = a_n + b_n\, HRD_{t-1} + c_n\, DM_t + m_n\, FRD_t + e_{n,t} \qquad (1)$$

where $(HRN_t, HRD_t, FRD_t) \in \{(NKN_t, NKD_{t-1}, SPD_t), (SPN_t, SPD_{t-1}, NKD_t)\}$.

$$HRD_t = a_d + b_d\, HRN_t + c_d\, DM_t + m_d\, FRD_t + e_{d,t} \qquad (2)$$

where $(HRD_t, HRN_t, FRD_t) \in \{(NKD_t, NKN_{t-1}, SPD_{t-1}), (SPD_t, SPN_t, NKD_t)\}$.

Equation #	(1)	(2)	(1)	(2)
LHS var.	NKN	NKD	SPN	SPD
Coeff.	m_n (T-stat)	m_d (T-stat)	m_n (T-stat)	m_d (T-stat)
Regime 1	0.194 (9.955)	-0.061 (-1.172)	0.083 (2.312)	0.020 (0.443)
Regime 2	0.085 (2.376)	0.547 (2.764)	0.214 (1.987)	0.109 (1.456)
Regime 3	0.217 (11.103)	-0.068 (-1.510)	0.099 (2.096)	0.037 (0.649)
Regime 4	0.388 (9.803)	-0.033 (-0.307)	0.156 (6.323)	-0.009 (-0.275)
Test[a]	33.296 (0.000)	9.317 (0.025)	3.612 (0.307)	2.285 (0.515)

Notes:

(a) Wald test statistics are for the null hypothesis that all coefficients of Regimes 1 to 4 for the column are identical. P-values are reported in parentheses.

Table 3 Asymmetric Effect on Cross-Market Dependence in Stock Returns

OLS Regression:

$$HRN_t = a_n + b_n\ HRD_{t-1} + c_n\ DM_t + (\mu_{n.0} + \mu_{n.1}I_n + \mu_{n.2}I_b + \mu_{n.3}I_v)FRD_t + en,t$$

where $(HRN_t, HRD_{t-1}, FRD_t) \in \{(NKN_t, NKD_{t-1}, SPD_{t-1}), (SPN_t, SPD_{t-1}, NKD_t)\}$. (3)

$$HRD_t = a_d + b_d\ HRN_t + c_d\ DM_t + (\mu_{d.0} + \mu_{d.1}I_n + \mu_{d.2}I_b + \mu_{d.3}I_v)FRD_t + ed,t$$

where $(HRD_t, HRN_t, FRD_t) \in \{(NKD_t, NKN_{t-1}, SPD_{t-1}), (SPD_t, SPN_t, NKD_t)\}$. (4)

Panel A: from SPD to NKN or NKD

Eq. #	(3)			(4)		
LHS	NKN			NKD		
Coeff.	$\mu_{n.1}$ (T-stat)	$\mu_{n.2}$ (T-stat)	$\mu_{n.3}$ (T-stat)	$\mu_{d.1}$ (T-stat)	$\mu_{d.2}$ (T-stat)	$\mu_{d.3}$ (T-stat)
Regime 1	0.125 (2.364)	0.115 (2.439)	0.027 (0.493)	0.037 (0.250)	0.029 (0.287)	0.018 (0.140)
Regime 3	-0.028 (-0.621)	0.096 (2.120)	0.026 (0.693)	-0.050 (-0.703)	0.061 (0.874)	-0.051 (-0.736)
Regime 4	-0.071 (-0.599)	-0.009 (-0.095)	0.145 (1.630)	0.017 (0.056)	0.008 (0.045)	0.166 (0.502)

Panel B: from NKD to SPN or SPD

Eq. #	(3)			(4)		
LHS	SPN			SPD		
Coeff.	$\mu_{n.1}$ (T-stat)	$\mu_{n.2}$ (T-stat)	$\mu_{n.3}$ (T-stat)	$\mu_{d.1}$ (T-stat)	$\mu_{d.2}$ (T-stat)	$\mu_{d.3}$ (T-stat)
Regime 1	0.101 (1.042)	0.028 (0.382)	-0.078 (-1.131)	-0.048 (-0.346)	-0.158 (-1.357)	-0.254 (-2.209)
Regime 3	-0.035 (-0.234)	0.067 (0.731)	0.025 (0.242)	-0.096 (-0.617)	-0.051 (-0.282)	0.170 (0.959)
Regime 4	0.022 (0.306)	-0.012 (-0.255)	-0.022 (-0.416)	0.005 (0.073)	-0.231 (-3.357)	-0.004 (-0.051)

Table 4 Cross-Market Dependence in Volatility of Stock Returns

Model:

$$e_{n,t} \mid \Omega(j) \sim N(0, h_{n,t}) \qquad j \in \{TKC_t, NYC_t\}$$

$$h_{n,t} = \omega_n + \alpha_n (e_{n,t-1})^2 + \beta_n h_{n,t-1} + \gamma_n DM_t + \delta_n (FRV_t)^2 +$$

$$(\rho_{n,0} + \rho_{n,1}I_n + \rho_{n,2}I_b + \rho_{n,3}I_v)(r_t)^2 \qquad (5)$$

or

$$e_{d,t} \mid \Omega(j) \sim N(0, h_{d,t}) \qquad j \in \{TKO_t, NYO_t\}$$

$$h_{d,t} = \omega_d + \alpha_d (e_{d,t-1})^2 + \beta_d h_{d,t-1} + \gamma_d DM_t + \delta_d (FRV_t)^2 +$$

$$(\rho_{d,0} + \rho_{d,1}I_n + \rho_{d,2}I_b + \rho_{d,3}I_v)(r_t)^2 \qquad (6)$$

where $\Omega(j)$ denotes the information set containing domestic and foreign daytime and overnight stock returns up to time j, e denotes the OLS residuals from the last regression, r_t is the most recent foreign unexpected returns (OLS residuals), and FRV_t is the foreign trading volume after removal of the day-of-week and holiday effects and nonstationarity.

Panel A: NKN

LHS.(eq.)	NKN (5)				
Coeff.	$\rho_{n,0}$ (T-stat)	$\rho_{n,1}$ (T-stat)	$\rho_{n,2}$ (T-stat)	$\rho_{n,3}$ (T-stat)	δ_n (T-stat)
Regime 1	-0.021 (-1.418)	0.011 (1.300)	0.023 (1.662)	-0.002 (-0.274)	-0.006 (-0.138)
Regime 3	-0.033 (-0.505)	0.026 (5.007)	0.015 (0.227)	-0.003 (-0.523)	0.135 (1.469)
Regime 4	-0.049 (-1.247)	0.048 (2.249)	0.007 (0.211)	-0.006 (0.354)	-0.040 (-0.415)

Panel B: NKD

LHS.(eq.)	NKD (6)				
Coeff.	$\rho_{d,0}$ (T-stat)	$\rho_{d,1}$ (T-stat)	$\rho_{d,2}$ (T-stat)	$\rho_{d,3}$ (T-stat)	δ_d (T-stat)
Regime 1	0.115 (1.082)	0.027 (0.938)	-0.101 (-0.976)	0.014 (0.327)	0.002 (0.011)
Regime 3	0.064 (0.413)	0.035 (3.315)	-0.088 (-0.566)	-0.010 (-0.847)	0.344 (1.555)
Regime 4	-0.200 (-2.393)	0.013 (0.482)	0.087 (1.386)	0.035 (1.376)	1.146 (1.735)

Panel C: SPN

LHS.(eq.)	SPN (5)				
Coeff.	$\rho_{n,0}$ (T-stat)	$\rho_{n,1}$ (T-stat)	$\rho_{n,2}$ (T-stat)	$\rho_{n,3}$ (T-stat)	δ_n (T-stat)
Regime 1	0.011 (0.213)	0.011 (0.623)	-0.005 (-0.101)	0.022 (1.139)	-0.036 (-1.778)
Regime 3	-0.145 (-3.132)	0.033 (1.301)	0.137 (3.069)	-0.074 (-3.820)	0.019 (1.117)
Regime 4	0.016 (0.488)	0.013 (1.067)	0.004 (0.129)	-0.022 (-1.897)	0.013 (0.396)

Panel D: SPD

LHS.(eq.)	SPD (6)				
Coeff.	$\rho_{d,0}$ (T-stat)	$\rho_{d,1}$ (T-stat)	$\rho_{d,2}$ (T-stat)	$\rho_{d,3}$ (T-stat)	δ_d (T-stat)
Regime 1	-0.247 (-4.954)	-0.061 (-6.032)	0.261 (5.461)	0.094 (4.387)	0.025 (1.315)
Regime 3	0.702 (1.756)	-0.136 (-0.955)	-0.554 (-1.538)	0.018 (0.182)	0.035 (0.369)
Regime 4	0.027 (0.398)	0.052 (2.581)	-0.041 (-0.587)	-0.010 (-0.475)	0.029 (0.418)

Table 5 Cross-Market Dependence in Trading Volume

Model:

$$HRV_t = \Sigma_i \pi_i\ HRV_{t-i} + \Sigma_i \theta_i\ FRV_{t-i} + \Sigma_i \phi_i | HRD_{t-i} | + \Sigma_i \lambda_i | FRD_{t-i} |$$

$$+ \phi^* \ I(HRD_{t-1}<0)) | HRD_{t-1} | + \lambda^* I(FRD_t<0)) | FRD_t | + v_t \qquad (7)$$

Panel A: NKV

	HRV = NKV FRV = SPV				
	Causality Test[a]			Asymmetric Effect[b]	
Coeff.	θ_i, i= 1,6 (p-value)	ϕ_i,i= 1,5 (p-value)	λ_i, i=1,6 (p-value)	ϕ^* (T-stat)	λ^* (T-stat)
Regime 1	4.268 (0.640)	11.510 (0.042)	24.807 (0.000)	-0.136 (-4.257)	-0.119 (-4.185)
Regime 3	3.155 (0.789)	1.534 (0.909)	6.585 (0.361)	-0.253 (-5.462)	-0.061 (-2.060)
Regime 4	21.863 (0.001)	10.199 (0.070)	10.378 (0.110)	-0.029 (-1.105)	-0.029 (-1.743)

Panel B: SPV

	HRV = SPV FRV = NKV				
	Causality Test[a]			Asymmetric Effect[b]	
Coeff.	θ_i, i= 0,5 (p-value)	ϕ_i,i= 1,5 (p-value)	λ_i, i=0,5 (p-value)	ϕ^* (T-stat)	λ^* (T-stat)
Regime 1	6.554 (0.364)	33.539 (0.000)	7.789 (0.254)	-0.061 (-3.367)	-0.035 (-1.657)
Regime 3	4.271 (0.640)	38.071 (0.000)	6.975 (0.323)	-0.008 (-0.290)	0.043 (1.396)
Regime 4	10.530 (0.104)	11.303 (0.046)	7.693 (0.261)	-0.049 (-2.598)	0.008 (0.550)

Notes:

(a) The causality test is a Wald test using White's (1980) heteroskedasticity- consistent covariance matrix, which is distributed as a chi-squared distribution with the degree of freedom of 5 or 6. P-values are reported in the regression.

(b) The estimated coefficients and corresponding t statistics are in parentheses.

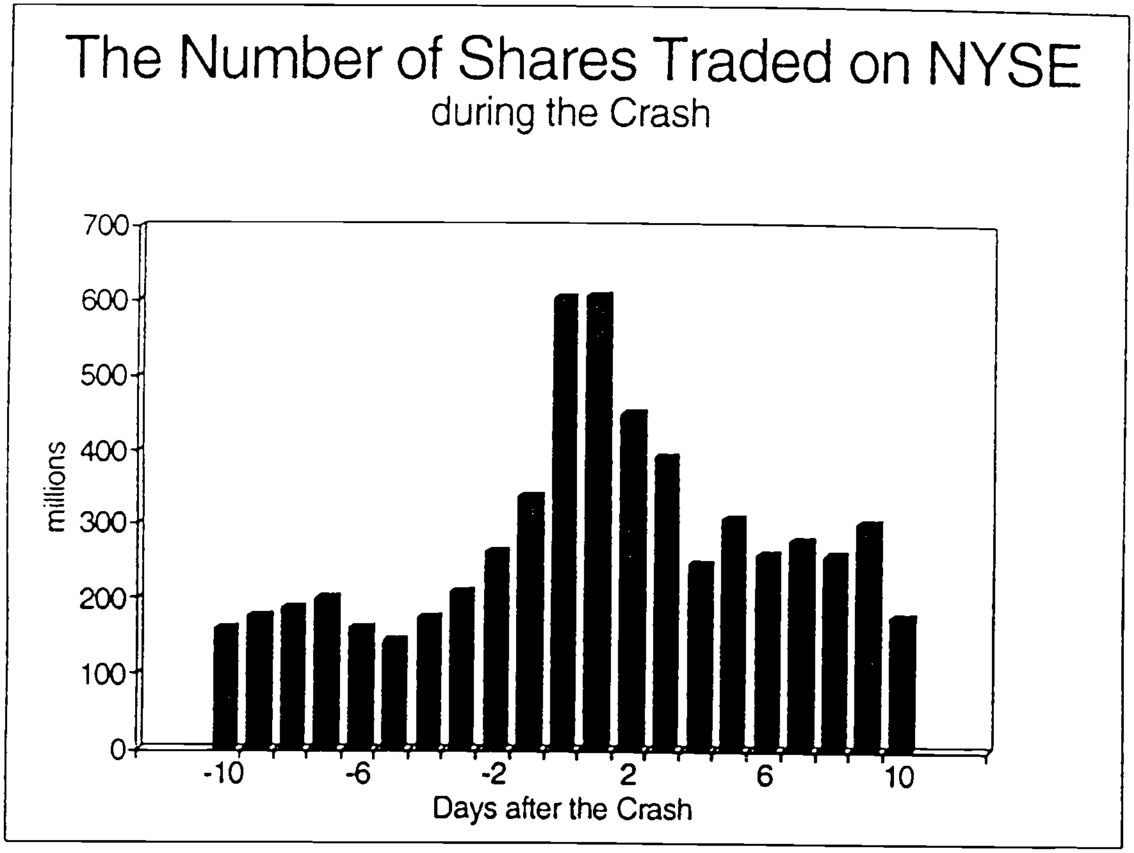

The Number of Shares Traded on NYSE
during the Crash
700
600
500
400
300
200
100
0
millions
-10
-6
-2
2
6
10
Days after the Crash

Figure 1

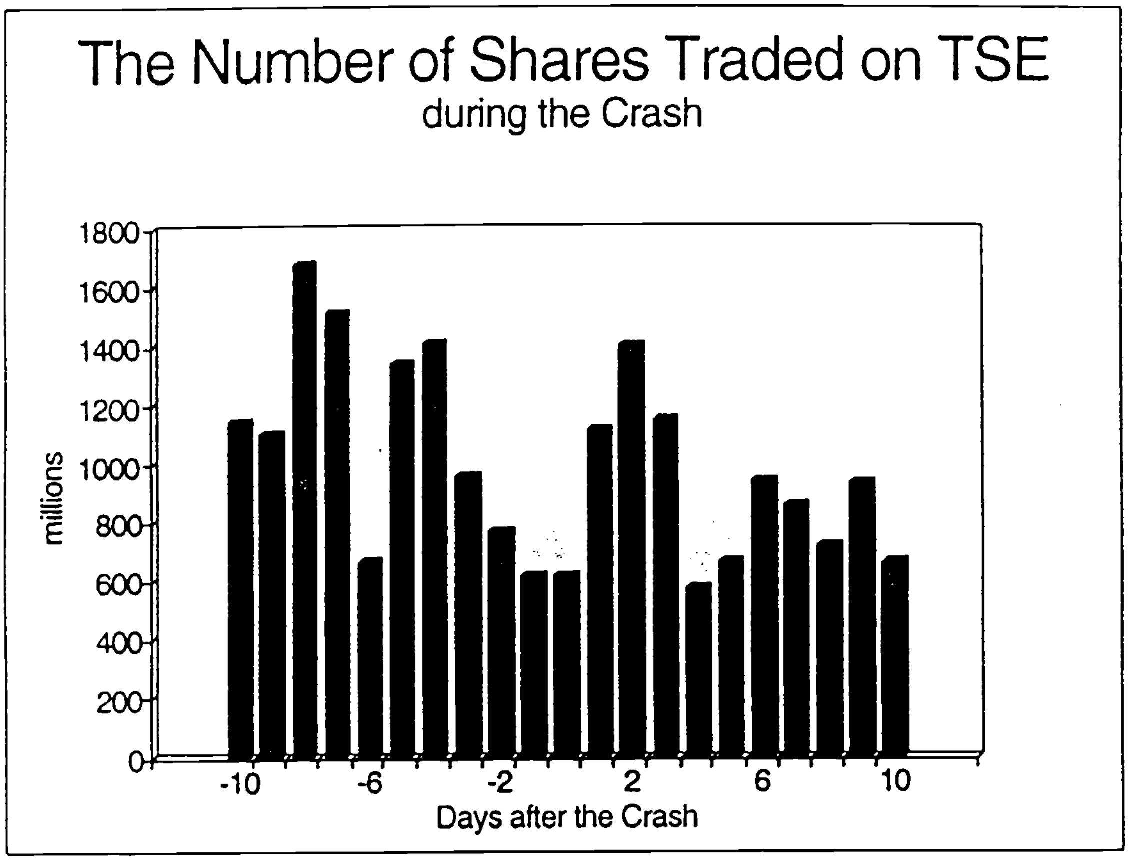
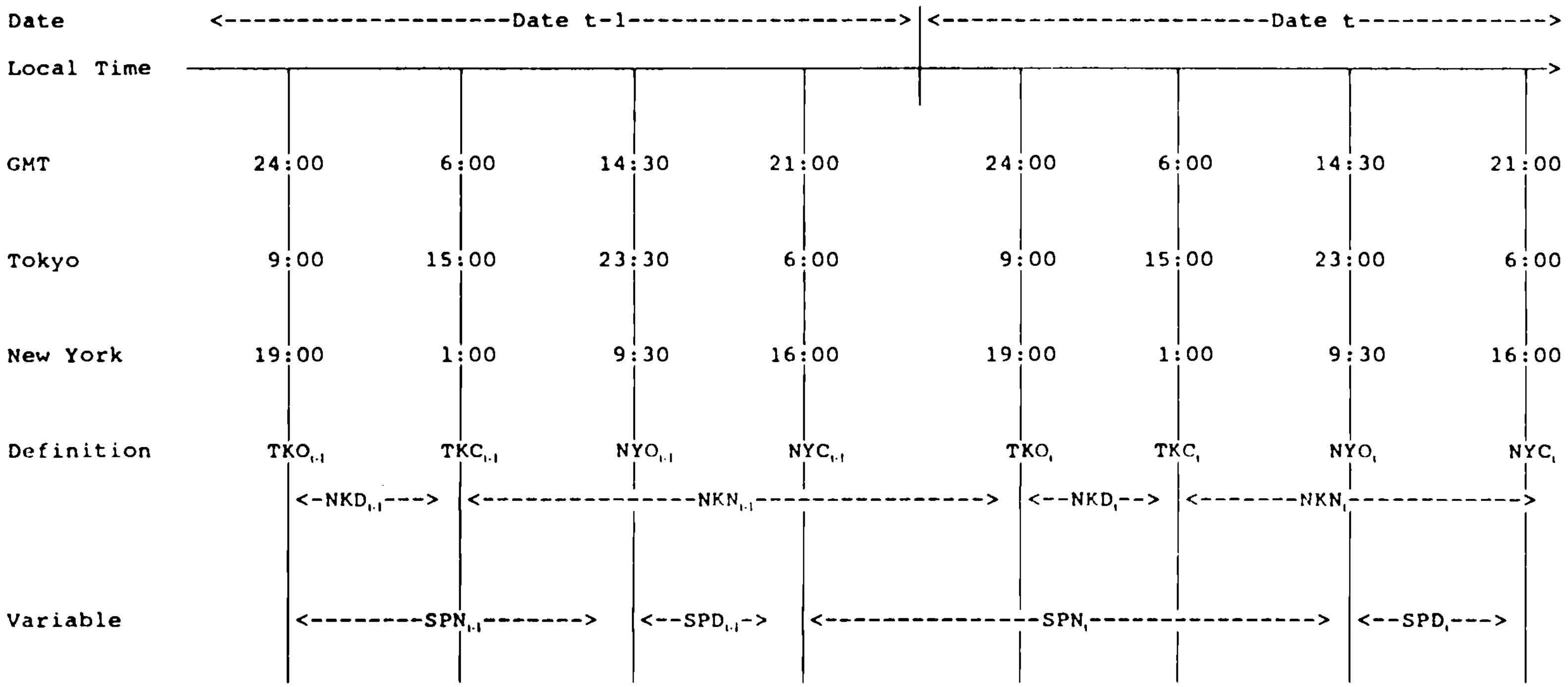

The Number of Shares Traded on TSE
during the Crash
1800
1600
1400
1200
1000
800
600
400
200
0
millions
-10
-6
-2
2
6
10
Days after the Crash

Figure 2

Figure 3

Figure 1 Timing and Notation



Notation:

TKO = opening time in the Tokyo market
TKC = closing time in the Tokyo market
NYO = opening time in the New York market
NYC = closing time in the New York market

NKD = Nikkei 225 daytime (open-to-close) return
NKN = Nikkei 225 overnight (previous close-to-open) return
SPD = S&P 500 daytime (open-to-close) return
SPN = S&P 500 overnight (previous close-to-open) return