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7 Price Volatility and Volume Spillovers between the Tokyo and New York Stock Markets

Wen-Ling Lin and Takatoshi Ito

7.1 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 three approaches. First, unlike other papers which analyze only price changes and volatility, this paper examines the effect of trading volume on

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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.

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 worldwide 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 follows from 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 Pitts [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.[3] 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 are likely to be positively influenced by foreign trading volume. We call this the market contagion hypothesis. Second, if correlations between international

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 overlap. A similar definition is also applied to trading volume and price volatility.

stock returns 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, Engle, and Ito 1993) implies such a relation. The reason is that volatility is a better measure of the rate of information flow than trading 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 (1990) 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 fourteen or thirteen hours, the information contained in the daytime return in one market is a subset of the information contained in the overnight return in the other market. Hence, we can examine the above two hypotheses—informational efficiency versus market contagion—by examining correlations between the daytime return in one market and the overnight returns in another market. Because 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 gross national product (GNP) announcement. This news is likely to affect the earnings of domestic export or import firms. According to the informational efficiency hypothesis, the domestic market is efficient in processing the foreign information so that 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. 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 the existence of 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 the model of Ross 1989). Similarly, volume spillovers do 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 marketwide information is not correlated due to infrequency 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 Standard and Poor's 500 (S&P 500) composite index plunged 22.9 percent, setting off international repercussions. The next day, the Nikkei 225 index declined 16.1 percent 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 7.1 and 7.2, 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, and volume spillovers when a large foreign price (volume) shock occurs. Since price changes contain information and noise, under either one of the above two possibilities there is an increase in uncertainty 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,

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, many stocks 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.

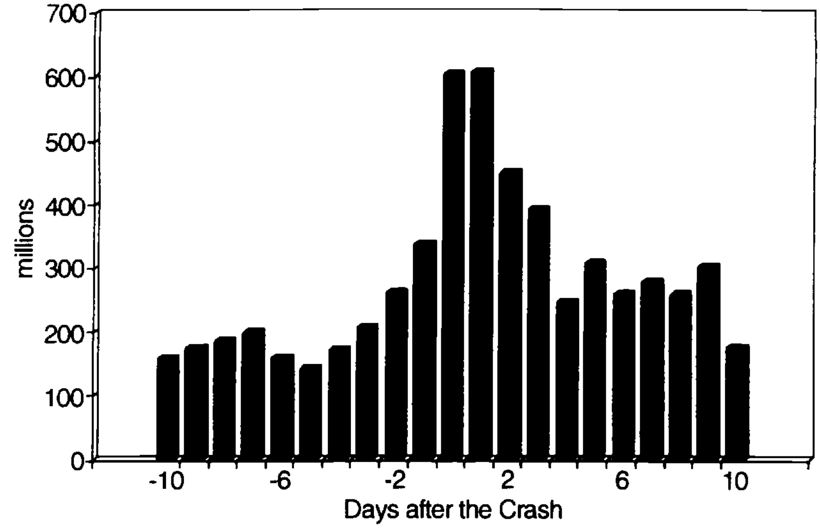

Fig. 7.1 The number of shares traded on the NYSE during the Crash

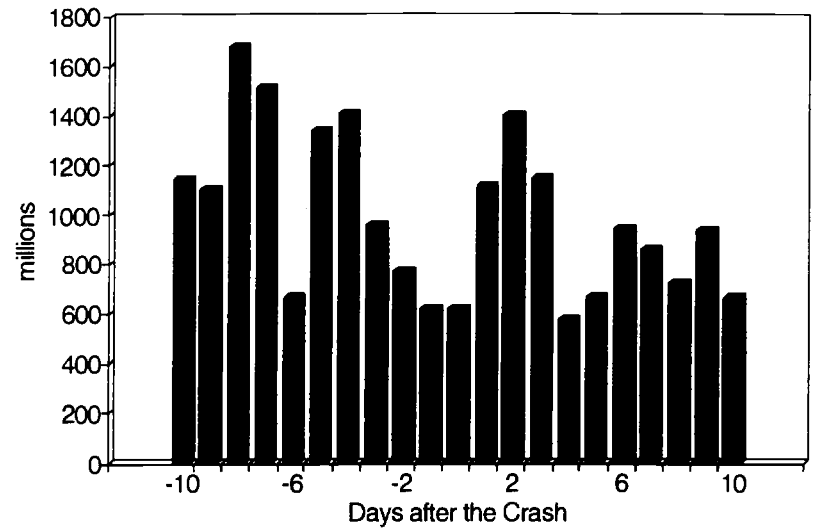

Fig. 7.2 The number of shares traded on the TSE during the Crash

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 7.2 describes the empirical framework; section 7.3 presents an analysis of the correlation of stock returns between the New York and Tokyo markets; section 7.4 reports empirical results for the causal relationship of volatility and trading volume between New York and Tokyo; section 7.5 examines the effect of the Crash on correlations between the New York and Tokyo stock markets; section 7.6 concludes the paper by summarizing our main findings.

7.2 The Model and Econometric Specification

7.2.1 The 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-invariant 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's 500 (S&P500) price indices, respectively, and suffixes D and N denote daytime and overnight, respectively. See figure 7.3 for detailed information about the timing of the markets.[5]

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 postholiday effects through a dummy variable, DM, and for the influence from abroad, we can write the domestic overnight return as[6]

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

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

5. According to analyses by Stoll and Whaley (1990) and Lin, Engle, and Ito (1993), the 9:15 quotes for the TSE and the 10:00 quotes for the NYSE were 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.

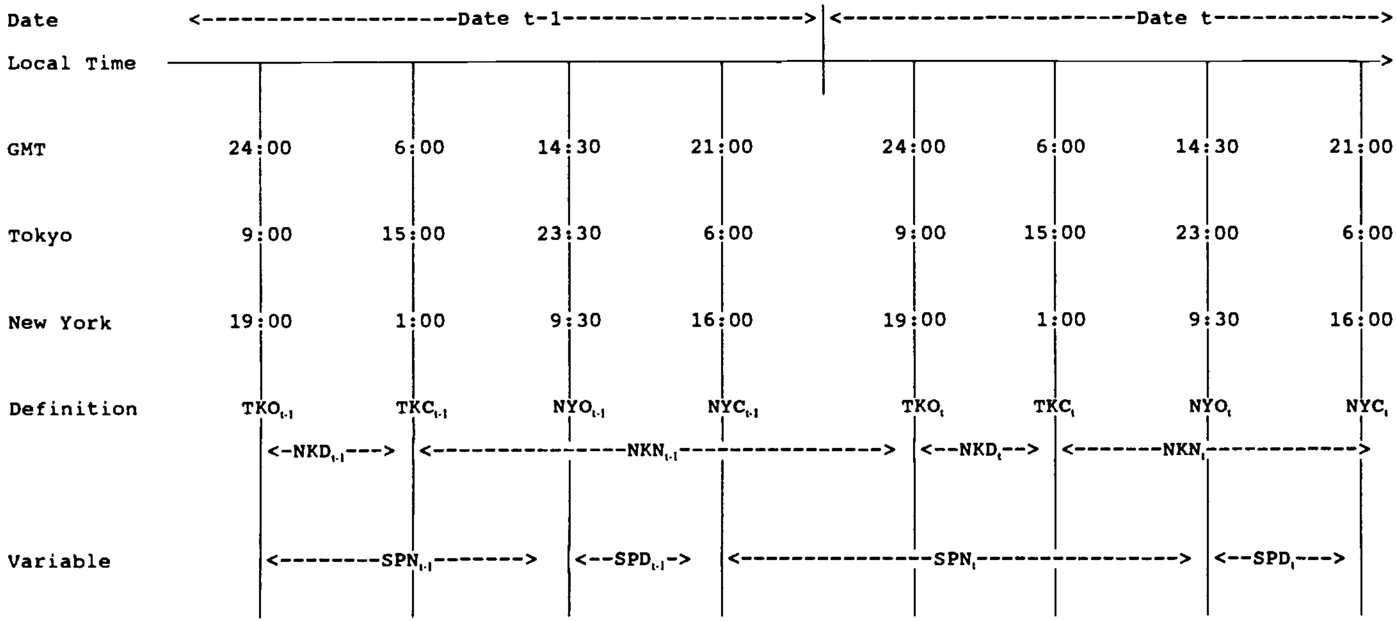

Fig. 7.3 Timing of the New York and Tokyo stock exchanges

Notes: 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.

We denote (x_t, y_t) as an element containing any pair of intradaily returns x_t and y_t on the New York Stock Exchange (NYSE) and the Tokyo Stock Exchange (TSE), $\{\}$ as a set of such elements, and E as the mathematical symbol for belonging to. Similar notations are used throughout the paper. 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:

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

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.[7] Since the information about the foreign market movement has become available to domestic investors at the open, $m_{d,t} FRD_t$ 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 versus market contagion hypotheses for the nature of international correlations of stock returns. Therefore, we allow $m_{n,t}$ to vary with dummy variables for periods of large volume, large shocks, and the sign of price changes in the foreign market.[8] 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, $m_{n,t}$ follows

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

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 7.3 to 7.4. To test for lagged spillovers, we also allow $m_{d,t}$ to vary with the above three dummies. $m_{d,t}$ is specified as

7. Note the time difference: Tokyo is ahead of New York by either fourteen hours or thirteen 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 also add dummies for a small return shock and a low trading volume to our specification of returns, volatility, and trading volume processes. In almost all cases, we find insignificant results. Therefore, we only report the results for a large return shock and a large trading volume.

$$(4) \qquad m_{d,t} = \mu_{d,0} + \mu_{d,1} I\{FRD_t < 0\} + \mu_{d,2} I\{|FRD_t| > \sigma(|FRD_t|)\} + \mu_{d,3} I\{FRV_t > \sigma(FRV)\}.$$

If the market is efficient, we expect that $m_{d,t} = 0$.

7.2.2 Volatility and Volume Process

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 processes of $e_{d,t}$ and $e_{n,t}$ follow

$$e_{n,t}|\Omega(j) \sim N(0, h_{nt})\; j \in \{TKC_t, NYC_t\}$$
$$e_{d,t}|\Omega(j) \sim N(0, h_{d,t})\; j \in \{TKO_t, NYO_t\},$$

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 $M(j)$. The conditional variance, $h_{d,t}$ or $H_{n,t}$, follows

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

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 ordinary least squares [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 spillovers of price volatility between the international stock markets as studied by Lin, Engle, and Ito (1993) and Hamao, Masulis, and Ng (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 large shock, and high volume, we write $\rho_{k,t}$, for $k = n$ and d, as

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

The specification of $\rho_{k,t}$ is motivated by the idea of Engle, Ito, and Lin (1990) for intermarket dependence in volatility and of Black (1976) and Christie (1982) for the leverage effect. In particular, when a large shock (due to a large rate of information flow) or large 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 a 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 one-hundred-day backward moving average of past volume.[9] 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 one-hundred-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

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

where $(HRV_t, FRV_t, HRD_t, FRD_t) \in \{(NKV_t, SPV_{t-1}, NKD_t, SPD_{t-1}), (SPV_t, NKV_t, SPD_t, NKD_t)\}$. In equation (7), like many studies of 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, a decrease in prices often suppresses

9. We denote the deviation of the trading volume from a one-hundred-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:

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

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.

the incentive to trade because of an increase in risk aversion, a short-sale constraint, or other market frictions. We also specify this effect in a cross-market framework.

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

7.3.1 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 NK225 and S&P500 as the stock price indices for our analysis.[10] 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 fourteen hours (in the winter) or thirteen hours (in the summer), so these trading hours do not overlap in real time.

Since we use the stock price indices, we need to be concerned 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 fifteen minutes during 1982–88. Consequently, the opening index defined only a minute after trading begins may not reflect all the relevant information. Lin, Engle, and Ito (1993) reported a wide range of correlation analyses between S&P500 and NK225 daytime and overnight returns and found that thirty (fifteen) 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 depends 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 was a bear-market period during which 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 these four subperiods is presented in table 7.1. Standard errors adjusted for heteroscedasticity and serial correlations (e.g., Newey

10. The Standard and Poor's 500 (S&P 500) is the equity-value weighted arithmetic mean of 500 stocks selected by Standard and Poor, Inc. The hourly data for the S&P 500 were 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 Sha.

Table 7.1 Data Summary

A. Nikkei 225

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

B. Standard and Poor's 500

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

[a]The number of observations in panel A is 566, 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 heteroscedasticity-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 and SPMAV denote the deviation of the log of trading volume from its one-hundred day backward moving average of past volume.

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

and West 1987) are reported in parentheses. Panel A of table 7.1 shows the results for the Tokyo overnight and daytime returns, and trading volume after removal of a trend component and the day-of-week and holiday effects. The Tokyo 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 7.1 shows the counterparts in the NYSE. The standard deviation of stock returns in the NYSE was higher in the Crash period, and trading volume was lower in the third and 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.

7.3.2 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.[11] Gauging this volatility dependence hypothesis is a first step toward understanding the informational efficiency versus 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 correlations increase during the Crash period, and whether the Crash increased the international transmission of stock returns and volatility afterwards.

Table 7.2 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 square estimation of equations (1) and (2) and by fixing $m_{n,t}$ or $m_{d,t}$ to be 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). The second and third columns in table 7.2 present the results for the impact of the New York daytime returns on the Tokyo daytime and overnight returns, whereas the fourth and fifth columns present the results for the effect of the NK225 daytime return to the S&P500 daytime and overnight returns. White's (1980) heteroscedasticity consistent

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

Table 7.2 Cross-Market Dependence in Stock Returns

OLS regression:
(1) $HRN_t = a_n + b_n HRD_{t-1} + c_n DM_t + m_n FRD_t + e_{n,t}$,
where $(HRN_t, HRD_{t-1}, FRD_t) \in \{(NKN_t, NKD_t, SPD_t), (SPN_t, SPD_{t-1}, NKD_t)\}$.
(2) $HRD_t = a_d + b_d HRN_t + c_d DM_t + m_d FRD_t + e_{d,t}$,
where $(HRD_t, HRN_t, FRD_t) \in \{(NKD_t, NKN_{t-1}, SPD_{t-1}), (SPD_t, SPN_t, NKD_t)\}$.

Equation No.	(1)	(2)	(1)	(2)
LHS Variables	NKN	NKD	SPN	SPD
Coefficients	m_n (*t*-statistic)	m_d (*t*-statistic)	m_n (*t*-statistic)	m_d (*t*-statistic)
Regime 1	0.194	−0.061	0.083	0.020
	(9.955)	(−1.172)	(2.312)	(0.443)
Regime 2	0.085	0.547	0.214	0.109
	(2.376)	(2.764)	(1.987)	(1.456)
Regime 3	0.217	−0.068	0.099	0.037
	(11.103)	(−1.510)	(2.096)	(0.649)
Regime 4	0.388	−0.033	0.156	−0.009
	(9.803)	(−0.307)	(6.323)	(−0.275)
Test[a]	33.296	9.317	3.612	2.285
	(0.000)	(0.025)	(0.307)	(0.515)

Note: LHS variables = left-hand-side variables.

[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.

standard errors are reported in the parentheses. Several conclusions emerge from table 7.2.

First, the first column in table 7.2 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 7.3. 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 is 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 correlations 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 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.[12]

7.3.3 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: (*a*) volatility effect—the cross-market dependence on stock returns (contemporaneous correlations or lagged spillovers) is greater when the volatility increases; (*b*) volume effect—the cross-market dependence on stock returns is greater when international stock return correlations or spillovers are associated with trading volume; (*c*) sign of price changes—a decline in prices, as opposed to an increase, increases 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, Engle, and Ito (1993); and Neumark, Tinsley, and Tosini (1991) have highlighted the importance of the increase in correlations of

12. We thank George von Furstenberg for his comments to us about these phenomena.

international stock returns during a 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 7.3, 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, Grossman, and Wang 1993; and LeBaron 1992) to an international context. Our interacting variables include dummies for a negative return, a large price shock (i.e., absolute returns greater than one standard deviation of returns in the sample), and large volume. Since the Crash period spans only three months (the number of observations is less than seventy), we report the results only for the other three periods in the following and section 7.4.

These empirical results are not strongly supportive of asymmetric effects on cross-market correlations. A large 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 large foreign trading 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 is 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 7.2 and 7.3 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 sales of uninformed traders who, upon 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 foreign trading 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 increases (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 7.2 and 7.3 dispute the market

Table 7.3 Asymmetric Effect on Cross-Market Dependence in Stock Returns

OLS regression:

(3) $HRN_t = a_n + b_n HRD_{t-1} + c_n DM_t + (\mu_{n,0} + \mu_{n,1}I_n + \mu_{n,2}I_b + \mu_{n,3}I_v)FRD_t + e_{n,t}$,
where $(HRN_t, HRD_{t-1}, FRD_t) \in \{(NKN_t, NKD_t, SPD_t), (SPN_t, SPD_{t-1}, NKD_t)\}$.

(4) $HRD_t = a_d + b_d HRN_t + c_d DM_t + (\mu_{d,0} + \mu_{d,1}I_n + \mu_{d,2}I_b + \mu_{d,3}I_v)FRD_t + e_{d,t}$,
where $(HRD_t, HRN_t, FRD_t) \in \{(NKD_t, NKN_{t-1}, SPD_{t-1}), (SPD_t, SPN_t, NKD_t)\}$.

A. From SPD to NKN or NKD

Equation No.	(3)			(4)		
LHS Variables	NKN			NKD		
Coefficients	$\mu_{n,1}$ (t-statistic)	$\mu_{n,2}$ (t-statistic)	$\mu_{n,3}$ (t-statistic)	$\mu_{d,1}$ (t-statistic)	$\mu_{d,2}$ (t-statistic)	$\mu_{d,3}$ (t-statistic)
Regime 1	0.125	0.115	0.027	0.037	0.029	0.018
	(2.364)	(2.439)	(0.493)	(0.250)	(0.287)	(0.140)
Regime 3	−0.028	0.096	0.026	−0.050	0.061	−0.051
	(−0.621)	(2.120)	(0.693)	(−0.703)	(0.874)	(−0.736)
Regime 4	−0.071	−0.009	0.145	0.017	0.008	0.166
	(−0.599)	(−0.095)	(1.630)	(0.056)	(0.045)	(0.502)

B. From NKD to SPN or SPD

Equation No.	(3)			(4)		
LHS	SPN			SPD		
Coefficients	$\mu_{n,1}$ (t-statistic)	$\mu_{n,2}$ (t-statistic)	$\mu_{n,3}$ (t-statistic)	$\mu_{d,1}$ (t-statistic)	$\mu_{d,2}$ (t-statistic)	$\mu_{d,3}$ (t-statistic)
Regime 1	0.101	0.028	−0.078	−0.048	−0.158	−0.254
	(1.042)	(0.382)	(−1.131)	(−0.346)	(−1.357)	(−2.209)
Regime 3	−0.035	0.067	0.025	−0.096	−0.051	0.170
	(−0.234)	(0.731)	(0.242)	(−0.617)	(−0.282)	(0.959)
Regime 4	0.022	−0.012	−0.022	0.005	−0.231	−0.004
	(0.306)	(−0.255)	(−0.416)	(0.073)	(−3.357)	(−0.051)

Note: LHS variables = left-hand-side variables.

contagion scenario. Moreover, the findings of no significant spillover from the foreign daytime return to the domestic daytime return are supportive of the informational efficiency hypothesis in that the domestic market can very quickly process the foreign information.

7.4 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) heteroscedasticity consistent covariance matrix.

7.4.1 The 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, Engle, and Lin (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 between the volatility of each market can be attributed to the dissemination of information flow across 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 7.4, we report the empirical results in table 7.4. A large shock or a large 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, Engle, and Ito (1993), who showed a lack of volatility correlation or spillover effects. These 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.

7.4.2 Volume Processes

Why might 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

Table 7.4 Cross-Market Dependence in Volatility of Stock Returns

Model:

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

(5) $h_{n,t} = \omega_n + \alpha_n (e_{n,t-1})^2 + \beta_n h_{n,t-1} + \gamma_n DM_t + \delta_n (FRV_t)^2 + (\rho_{n,0} + \rho_{n,1} I_n + \rho_{n,2} I_b + \rho_{n,3} I_v)(r_t)^2$

or

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

(6) $h_{d,t} = \omega_d + \alpha_d (e_{d,t-1})^2 + \beta_d h_{d,t-1} + \gamma_d DM_t + \delta_d (FRV_t)^2 + (\rho_{d,0} + \rho_{d,1} I_n + \rho_{d,2} I_b + \rho_{d,3} I_v)(r_t)^2$,

where $\Omega(j)$ denotes the information set containing domestic and foreign daytime and overnight stock returns up to time j, $e_{n,t}$ or $e_{d,t}$ 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.

A. NKN

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

B. NKD

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

C. SPN

LHS Variables (equation)	SPN (5)				
Coefficients	$\rho_{n,0}$ (*t*-statistic)	$\rho_{n,1}$ (*t*-statistic)	$\rho_{n,2}$ (*t*-statistic)	$\rho_{n,3}$ (*t*-statistic)	δ_n (*t*-statistic)
Regime 1	0.011	0.011	−0.005	0.022	−0.036
	(0.213)	(0.623)	(−0.101)	(1.139)	(−1.778)
Regime 3	−0.145	0.033	0.137	−0.074	0.019
	(−3.132)	(1.301)	(3.069)	(−3.820)	(1.117)
Regime 4	0.016	0.013	0.004	−0.022	0.013
	(0.488)	(1.067)	(0.129)	(−1.897)	(0.396)

Table 7.4 (continued)

D. SPD

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

Note: LHS variables = left-hand-side variables.

traders who can split their trades across markets increases, the correlation between volume in different markets will increase. A second factor is an increase in the dispersion of beliefs about the information revealed in other markets.

Table 7.5 reports the estimated processes for trading volume and shows that trading volume in one market cannot significantly Granger cause trading volume in the other markets. 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 percent 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 six degrees of freedom, 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 7.5. Literature has documented that volume becomes lower when returns fall than when returns rise. Studies attribute this

Table 7.5 Cross-market Dependence in Trading Volume

Model:

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

where $(HRV_t, FRV_t, HRD_t, FRD_t) \in \{(NKV_t, SPV_{t-1}, NKD_t, SPD_{t-1}), (SPV_t, NKV_t, SPD_t, NKD_t)\}$.

A. NKV

	HRV = NKV FRV = SPV				
	Causality Test[a]			Asymmetric Effect[b]	
Coefficients	$\theta_i, i = 0,5$ (p-value)	$\phi_i, i = 1,5$ (p-value)	$\lambda_i, i = 0,5$ (p-value)	ϕ^* (t-statistic)	λ^* (t-statistic)
Regime 1	4.268	11.510	24.807	−0.136	−0.119
	(0.640)	(0.042)	(0.000)	(−4.257)	(−4.185)
Regime 3	3.155	1.534	6.585	−0.253	−0.061
	(0.789)	(0.909)	(0.361)	(−5.462)	(−2.060)
Regime 4	21.863	10.199	10.378	−0.029	−0.029
	(0.001)	(0.070)	(0.110)	(−1.105)	(−1.743)

B. SPV

	HRV = SPV FRV = NKV				
	Causality Test[a]			Asymmetric Effect[b]	
Coefficients	$\theta_i, i = 0,5$ (p-value)	$\phi_i, i = 1,5$ (p-value)	$\lambda_i, i = 0,5$ (p-value)	ϕ^* (t-statistic)	λ^* (t-statistic)
Regime 1	6.554	33.539	7.789	−0.061	−0.035
	(0.364)	(0.000)	(0.254)	(−3.367)	(−1.657)
Regime 3	4.271	38.071	6.975	−0.008	0.043
	(0.640)	(0.000)	(0.323)	(−0.290)	(1.396)
Regime 4	10.530	11.303	7.693	−0.049	0.008
	(0.104)	(0.046)	(0.261)	(−2.598)	(0.550)

[a]The causality test is a Wald test using White's (1980) heteroscedasticity-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.

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 7.5 show evidence of the asymmetric effect of returns on trading volume not only in the domestic market, but also across markets.[13]

13. We also test for the asymmetric effect of a large lagged return shock and a large lagged trading volume on the current trading volume. We find insignificant results. Therefore, the results are not reported.

7.5 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 worldwide 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 7.3.2, 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 7.6 reports an OLS regression, similar to equation (2), for hourly stock returns. The standard errors are also adjusted for heteroscedasticity. 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 were skeptical about the causes of the Crash. Thus, uncertainties about the cause of the Crash may have led to a lag adjustment of this information and a significant return spillover.

7.6 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, Engle, and Ito 1993; and Hamao, Masulis, and Ng 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 fi-

Table 7.6 Returns Spillovers during the Crash Period—Hourly Analysis

A. Spillovers from SPD to NKD

NK225[a] Hourly Returns	9:15–10	10–11	11–13:15	13:15–14	14–15
SPD	0.088[b]	0.113	0.039	0.082	0.163
	(2.844)	(2.231)	(0.845)	(3.024)	(2.792)

B. Spillovers from NKD to S&P500 Hourly Stock Returns

S&P500[a] Hourly Returns	10–11	11–12	12–13	13–14	14–15	16–16:30
NKD	0.055[b]	−0.020	−0.028	0.108	0.012	0.053
	(0.463)	(0.359)	(−0.774)	(2.289)	(0.191)	(1.002)

[a]The first row lists the time span for hourly stock returns of dependent variables, and the first column lists the exogenous variable.

[b]The estimated coefficients and corresponding t-statistics (calculated using White's [1980] heteroscedasticity-consistent covariance matrix) are in parentheses.

nancial disturbances results from the first source, as the model of Campbell, Grossman, and Wang (1993) predicts, 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, Engle, and Ito (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 large shock occurs. In addition, we found no evidence on volume, volatility, or return spillovers for the 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 to foreign information efficiently.

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Comment Allan W. Kleidon

The paper by Wen-Ling Lin and Takatoshi Ito (henceforth LI) falls in the general category of market microstructure, which includes the structure of markets, the causes of transaction-to-transaction price movements, and the way in

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which information from diverse individuals is aggregated into market prices. The paper makes two main contributions. First, it adds to the growing literature that exploits the potential information in the market behavior of assets that are traded in different international markets, but that are identical or at least very similar. LI examine the behavior of broad market indices in Japan and the United States, namely, the Nikkei 225 index from the Tokyo Stock Exchange and the S&P 500 index from the New York Stock Exchange (NYSE).

Second, LI provide detailed statistics on price and volume in these markets, including mutual statistical dependencies. Overnight and daytime returns for several time periods are examined, as are some intraday (hourly) returns during the Crash of October 1987. In general the statistical analysis is thorough and reliable, although the robustness of large sample test statistics for the current application is a potential issue.

My main concerns relate to the interpretation of results. To illustrate, much of the paper tests ostensibly alternate theories of market microstructure: the "market contagion" and the "informational efficiency" hypotheses. The conclusion reached (section 7.3.3) is that the data support the informational efficiency hypothesis but not the market contagion hypothesis. For several reasons, I do not believe that the results currently support such strong conclusions. The use of data from different countries raises questions about the extent of integration across markets and the possible effects of different types of market structure. The main issue, however, is the importance of precision in empirical inferences drawn from ostensibly competing hypotheses.

Integration of Japanese and U.S. Markets

One theme of the paper is to examine the degree and causes of correlations across these markets. While minute attention is placed on some analysis—for example, hourly returns around the 1987 Crash—the paper does not attempt a broader perspective on the level of integration. It seems clear from a comparison of price paths for Japanese versus U.S. stocks that there are key differences in behavior across the markets over the period examined, which indicates either imperfect integration or imperfect comparability. For example, Japanese price movements are closely linked to Japanese land prices, which contain idiosyncratic elements. Stone and Ziemba (1993) conclude that there is little evidence of a bubble in Japan's essential land or stock markets, despite the dramatic declines in both these markets in the early 1990s that are not observed in U.S. returns.

Frankel, in his introduction to this volume, comments that it is surprising "that the authors find no evidence that volatility in Tokyo is associated with volatility in New York, as they have found in earlier work on the foreign exchange market." The foreign exchange market is one of the most highly integrated international markets, which may explain at least some of the differences.

Effects of Market Structures

Even in the foreign exchange market, however, there are clear differences in the behaviors of quotes that are generated simultaneously by traders physically located in different countries (see, e.g., Bollerslev and Domowitz 1993 and Hsieh and Kleidon 1992). This is particularly evident around the "open" and "close" of trading. Kleidon and Werner (1993) document differences in the behavior of prices for cross-listed securities on the London and New York exchanges when New York opens and London closes. LI's overnight and daytime return series, which are defined around open and close of trade, may be influenced by market peculiarities. Although the authors control for nontrading at open, more attention may be warranted.

Precision in Empirical Inferences

Great care must be exercised in drawing inferences from market microstructure theories. It is not clear that the empirical inferences drawn in this paper are precise. Consider the clearest statement in the paper concerning the alternate models examined (section 7.3.3):

> The aim of the above analysis in tables 7.2 and 7.3 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 sales of uninformed traders who, upon 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 foreign trading 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 increases (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 7.2 and 7.3 dispute the market contagion scenario. Moreover, the findings of no significant spillover from the foreign daytime return to the domestic daytime return are supportive of the informational efficiency hypothesis in that the domestic market can very quickly process the foreign information.

This is a key part of LI's analysis, yet the inference seems fragile at best. The following attempts to lay out the paper's logic in seven steps and to suggest plausible alternative inferences.

1. *Campbell, Grossman, and Wang* [henceforth CGW] *(1993) imply that uninformed domestic traders may become more risk averse when they observe a price drop in the foreign market, leading them to sell to domestic informed*

traders. CGW distinguish between price changes due to public information and price changes due to a change in the risk aversion of uninformed investors that leads them to change their holdings. If uninformed traders seek to sell stocks, then risk averse informed investors will require compensation for increasing their holdings. CGW assume that volume provides information about the cause of price changes. Public information results in price changes with low volume and no changes in required return for the marginal holder, while increased risk aversion of uninformed investors leads to high volume (as they sell stocks) and high future expected returns (to compensate the marginal risk averse traders who now hold a larger portfolio of risky stock). The second scenario provides a source of negative serial correlation in returns (lower returns now, higher returns next period). The empirical implication is that price changes with high volume indicate a source of negative serial correlation (or lower positive serial correlation). CGW document evidence consistent with their model.

CGW do not address foreign versus domestic trading. Theoretical questions arise concerning the possible effects on their model if informed traders can respond in the overseas market to price changes there. LI note a relative absence of cross-market trading (section 7.4.2), so let us assume that traders are restricted to their domestic markets. The argument as stated in LI makes no distinctions based on the cause of the overseas price change, which presumably may be due to public information, to information available to the informed, or to noninformation-based events (such as the actions of uninformed overseas investors).

In any case, unless the domestically informed knew perfectly the cause of the overseas price decline, most models would suggest that a rational domestic response would be a domestic decline. Certainly LI do not rule out overseas price changes based on information, but assume an additional effect, namely, increased risk aversion by the domestic uninformed, leading to a sell-off to domestic informed traders. The link between overseas price declines and domestic uninformed risk aversion is outside CGW, and is simply assumed in LI.

2. *This causes expected returns to increase and the price to drop*. As noted above, the domestic price may fall even absent the assumption of increased risk aversion by the uninformed. The argument here seems to be that such a domestic response would be exacerbated. Note that foreign daytime returns occur when the domestic market is closed, that is, during the domestic overnight. Hence the enhanced domestic price drop will be observed at the start of trading in the next domestic daytime trading period, so that the overnight return will be lower and the following daytime return higher than otherwise expected.

3. *Consequently the effect of foreign daytime returns on domestic overnight (daytime) returns increases (decreases) when the foreign trading volume increases*. LI posit a contemporaneous correlation between foreign daytime and domestic overnight returns that is higher when volume increases. The key question, What volume is implied by the theory?

The answer must be *domestic* volume, since the point of CGW is the accommodation of (domestic) uniformed traders whose risk aversion changes, and LI do not assume cross-market trading. However, LI explicitly look at the effect of *foreign* volume: "[T]he effect of foreign trading volume incorporates the implication of the market contagion hypothesis" (section 7.2.1). Table 7.3 examines foreign but not domestic volume. The story in CGW begins with the increase in uninformed traders' risk aversion, which LI identify with an overseas price decline irrespective of its cause. The increase in risk aversion then induces high domestic volume as traders rebalance their portfolios. Without something to tie the paper's market contagion story to foreign volume, the current results do not seem to shed light on the issue. Moreover, the relevant test should look at domestic volume, as in CGW.

4. *The findings of contemporaneous correlations of stock returns across markets in tables 7.2 and 7.3 dispute the market contagion scenario.* This conclusion seems unrelated to the argument. The paper is silent about the causes of the overseas decline, which seem irrelevant for the assumed increase in risk aversion of *uninformed* traders. There is nothing in the market contagion scenario as argued from CGW that prohibits a contemporaneous correlation between overseas daytime returns and domestic overnight returns. Indeed, I would generally expect that information-based models would imply a contemporaneous correlation between foreign and domestic returns, irrespective of any incremental effects of increased risk aversion for domestic uninformed traders.

5. *Under the informational efficiency hypothesis, the foreign price changes are informative regarding contemporaneous domestic returns.* The paper explicitly accepts such contemporaneous correlation, but informational efficiency and the stated market contagion scenario of CGW are not mutually exclusive.

6. *Hence a higher rate of information in the foreign market increases contemporaneous correlations between foreign and domestic returns.* However the "empirical results are not strongly supportive" (section 7.3.3), with a possible exception of New York to Tokyo.

7. *No significant spillover from foreign daytime return to the domestic daytime return supports informational efficiency.* This conclusion seems too strong since the market contagion alternative being considered is explicitly stated to imply that there will be a lower correlation than otherwise between foreign daytime and domestic daytime returns (see [3] above). Conceivably the observed results in LI could be due to an interaction between, on the one hand, domestic inefficiency that causes positive correlation between domestic overnight and domestic daytime returns, and, on the other hand, market contagion that induces some negative correlation between domestic overnight and domestic daytime returns.

Conclusions

The paper by Lin and Ito provides valuable information concerning empirical regularities linking Japan's Nikkei 225 index and the U.S. S&P 500 index. Nevertheless, much work remains before these empirical results are tied to rigorous tests of market microstructure theories.

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Comment George M. von Furstenberg

Lin and Ito offer careful estimates of correlations of one stock-price index change with another, recorded in the daily sequence of trading in the United States and Japan. Their time-varying estimates are conditioned by aspects of these changes, such as direction and relative size, by changes in foreign trading volume, and by "unexpected" returns in foreign and domestic markets. Surprises are inferred from ordinary least squares (OLS) residuals of equations that use stock-market data alone. The thrust of this comment is that the substantive composition of the news, its rate of capture in markets over any twenty-four-hour period, and the time allowed for disentangling the news are crucial to the question of what correlations to expect.

In particular, increasing positive correlations of rates of return between successive stock markets cannot provide conclusive evidence of globalization. Rather, globalization could be perfect even while these correlations are zero or negative. If stock prices are formed efficiently, and with the same functional regard for news about changing fundamentals everywhere, both the Tokyo and New York markets would apply the same pricing function, making them en-

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tirely integrated and global. Even then coefficients on *daytime* returns in one market, in the preferred regression for the *overnight* returns in the market trading next, may differ by location of markets. The reasons can easily be misinterpreted.

For instance, if one market's intraday trading span can capture less information than that of another or if one market has more time to figure out the heterogeneous content of the news that may have given rise to intraday stock-price movements in the prior market, symmetry should not be expected. Conversely, statistical evidence of asymmetry between New York to Tokyo (on the next date) versus Tokyo to New York (on the same date) should not necessarily be attributed to national differences in acuity: the critical issue is whether there was good reason for successive markets to react differently to what may have been heard equally well by all.

Reasons for Asymmetry

Every country's major market contains stock-price reaction to news of local origin and significance that adds noise to the signals which foreign markets are trying to pick up. Now assume that variance levels of country-specific noise are about the same in each market, but the amount, that is, the total variance, of global signal content captured is proportional to the daytime length of operation of a particular market, as in a diffusion process. Then the signal-to-noise ratio of, say, the Frankfurt market, open for only two hours per day during much of the period October 1985 through 1991 analyzed by the authors, would be less than a third of that of the New York market, open for six and one-half and then seven hours a day. German investors would rationally expect that much less predictive power of the German for the U.S. market than vice versa, and so would investors elsewhere. Indeed, all investors should rather look to the London market, which overlaps and straddles trading hours in Frankfurt, for whatever advance information there may be on the overnight returns to be expected in New York by the time it opens.

Lin and Ito refer instead only to the five-and-three-quarter-hour-wide span covered by the legs of "daytime" trading in the Tokyo market as measured. They ignore the six hours of trading available in the London market just before the start of "daytime" trading in New York, which they set at 10 A.M. local time. U.S. "overnight" returns are thus left statistically uninformed of anything that transpired (*a*) after the New York close on the previous date and before 9:15 A.M. Tokyo time on the same date, a time distance of three and one-quarter hours, and (*b*) after the Tokyo close and 10:00 A.M. New York time on the same date, a time distance of nine hours. Segment *b*, covering the active time in the Middle East and Europe, is not only much longer but also much more information intensive than segment *a*, which contains prime time in the Pacific and along its rim for what business news there is before a time (9:15 A.M.) soon after the Tokyo open.

As trading moves from New York across the international date line to Tokyo, the next overnight returns, registered in Tokyo, will be uninstructed by the same major segment *b,* since they are statistically informed of only the prior daytime returns in New York. Continuing in chronological order on from Tokyo back to New York, both on the next date, will again find overnight returns in New York missing the major information segment *b,* but for the first time on the next date. Overnight returns in New York on one date followed by overnight returns in Tokyo on the next date will have the same observation on (*b*) missing. By contrast, overnight returns in Tokyo followed by overnight returns in New York on a single date are affected by different observations on (*b*) that are asynchronous and quite possibly serially uncorrelated.

The fact that Tokyo's close is almost three times as far removed in time from New York's soon-after-open as vice versa can give rise to yet more asymmetries in first and second moments. If news arrives in a heterogeneous glob whose composition can only gradually be disentangled, the expected *precision* of a market's reaction will rise with the length of time available for news analysis. As I emphasized already in my paper with Jeon (von Furstenberg and Jeon 1989, 136), news that affects one market can be redistributive as well as corroborative and anything in between, and still be entirely global in the way it affects, or on balance fails to affect, prices in another stock market. Redistributive news affects two countries in opposite directions either because their economies, like those of oil-exporting and oil-importing countries, are different, or because their major industries compete, like two grain-exporting countries, each standing to gain from crop failures in the other. Instead of being good for one and bad for another or vice versa, corroborative news affects countries' welfare in the same direction on account of common exposure and impact. Most global news has some redistributive as well as corroborative components, thereby differentiating the expected stock-price reactions by country.

Why time distance matters can best be shown by proceeding in a manner analogous to that of Goodfriend (1992). He showed how news that may arise from one of two initially indistinguishable causes or any combination thereof gets decoded, and thus affects markets, in two successive stages. Assume, therefore, that news originating during daytime trading in both the Tokyo and New York markets arrives as a glob that moves these markets for reasons not instantly ascertainable. What is known, for the sake of simple illustration, is that there is a 75 percent prior probability that such news will be perfectly corroborative, calling for matching percentage price changes in both markets. On the other hand, there is a 25 percent probability that the news is perfectly redistributive, calling for exactly opposite percentage changes in price. Thus any news on foreign stock prices will be met predictably by a 50 percent response in the next market, as long as the news glob remains unidentified.

If the New York market is up 1 percent in daytime trading, the Tokyo overnight rate of return on the next date should be 0.5 percent, since $0.75(1) + 0.25(-1) = 0.5$. If "Tokyo" has too little time to disentangle the "New York" news, meaning any market-relevant news that transpired during the hours of daytime trading in New York earlier, its movements would follow those of New York rather closely. Now consider the processing of news originating during Tokyo daytime trading that lifted its index by 1 percent. While the average reaction of "New York" to "Tokyo" on a single date would again be a 0.5 percent rise, investors transacting in New York will have had much more time to disentangle news from the Tokyo market. Furthermore, they will have received important help from the analytical power concentrated in London's financial community before they must act. Assuming, therefore, that what is behind Tokyo's 1 percent rise has been discovered by 10 A.M. New York time, overnight returns in New York will be +1 percent three-quarters of the time and −1 percent one-quarter of the time.

The implied rise in the standard error of the coefficient of 0.5 that would be estimated on Tokyo's daytime rate of return in the New York market does not indicate that news gets fuzzier or the conditional reaction to news less predictable as the time interval that has elapsed from the news event to (thirty minutes after) the next market's opening increases. Rather, it implies that there has been more time to figure out the substantive content of the news. Less statistically predictable reaction to a foreign stock-price index change thus may be due to a more precise reaction to each of the different types of events that could have caused it. Markets that are efficient in identifying the content of specific news events are the enemy of Pavlovian correlations, and not their friend as frequently implied.

Developing Heterogeneity of Beliefs and Its Stock-Price Effects

A number of authors have linked trading volume with heterogeneity of beliefs. Lin and Ito note, however, that the link of volume change (the deviation of current volume from a backward moving average of one hundred daily observations on number of shares traded in their study) to stock-price index change within or across countries is less certain. To provide insight into the latter relation, consider two investors who, after a period of steadiness, are confronted with what could be a permanent change in noisy fundamentals. Once fully recognized, this change may be such as to imply a large decline in stock prices under the universal pricing function. If one allowed the two investors to trade in each other's market, they could be assigned to different countries, but there will be no such elaboration here.

Instead, the investors differ in only one respect, the strength of their prior beliefs in the endurance of the old and previously well established fundamentals. Investor i may also fear being misled by noise more than missing out on news. He would then be much more willing to discount evidence of something new because he is most concerned about avoiding the Type I error that would be committed by rejecting the old null when it remains true. Investor j, on the other hand, will take more risks of being misled by noise for fear of missing out on news. Seeking to avoid Type II errors, she seeks quickly to grasp any change in fundamentals that might have occurred. Thus either investors i and j

view the world differently, one thinking that permanent changes in fundamentals are much rarer than the other, or the types of errors that most concern them are different for reasons that may have to do with differences in tastes, responsibilities, or social circumstances. Investor i may be called a slow learner and investor j a fast learner, without impugning the rationality of either.

Using the information-theoretic design of Taylor (1975) as interpreted in von Furstenberg 1990, the precision which investor i attributes to his prior beliefs can be represented by the inverse of the variance assigned to the mean of the old fundamentals, $w_i \equiv s_0^{-2}$. A low variance means that the investor has had the time and experience to pin down the enduring fundamentals supporting the status quo. In that case it will take a great deal of evidence to convince him of new fundamentals should the status quo ever change. When a covert change in fundamentals occurs that, if recognized, would call for the stock-price index to change by dF, this change has to be inferred from the unfolding $0 \rightarrow t$ data points by all investors. Simplifying by assuming a commonly known, time-invariant level of the variance of data on the new fundamentals, s^2, the inverse of the variance of the mean of the first t observations, if accumulated under the new regime, is $z(t) \equiv t/s^2$. Then the heterogeneity of beliefs about the present state of fundamentals, $x(t)$, that would be expected by an inactive (nontrading) observer with private knowledge of dF is

$$(1) \qquad E[x_i(t) - x_j(t)] = [w_i/(w_i + z(t)) - w_j/(w_j + z(t))]\, dF.$$

Assume now that $w_j = \alpha w_i$ and $\alpha < 1$, meaning, the precision which investor i attributes to his beliefs in the persistence of the status quo ante is greater than j's precision. Substituting for w_j and maximizing the expected gap between these beliefs with respect to $z(t)$, heterogeneity of beliefs turns out to be greatest when $z(t) = \alpha^{0.5} w_i$, or $t = \alpha^{0.5}(s/s_0)^2$. For example, if $(s/s_0) = 4$ and $\alpha = 0.25$, it would take eight trading periods or observations on the new fundamentals for the maximum heterogeneity of beliefs to be reached about such fundamentals.

Slow learners eventually catch up with fast learners in gaining a complete and correct understanding of the new fundamentals. Yet the distance between the beliefs of slow and fast learners, starting out from a common position, widens for a time after any permanent, but not immediately clear, shock to fundamentals, and then declines.

The greater the difference in the speed of learning or the smaller α, the faster convergence of beliefs sets in. For $\alpha << 1$, the gap between beliefs widens and reaches a maximum soon after the first occurrence of noisy data generated under the new fundamentals. Because the total amount of learning that causes the market-weighted average of $x_i(t)$ and $x_j(t)$, and hence current stock price levels, to change, is always greatest right after the unobserved change in fundamentals and then steadily declines, stock prices fall at a decreasing rate from the initial to the lower equilibrium. Volume, however, being tied to heterogeneity of beliefs, peaks in the *intermediate* stages of the learning process. If the peak comes early so that the rise is steep and short and the decline long, a positive correlation between volume and the size of the absolute price change could predominate. Conversely, if the peak is reached much later because α is not far below 1, there may be zero or negative correlation. The reason is that prices change by decreasing absolute amounts throughout while volume builds in the initial phases of learning about the new fundamentals.

Conclusion

The theory of information extraction can suggest alternative possibilities, but it cannot predict the sign and size of correlations actually found between the New York and Tokyo stock exchanges. For instance, increased globalization need not produce higher positive correlations or greater symmetry in the response of successive national stock-market rates of return to innovations. Perhaps equally counterintuitive, more precise processing of information may *reduce* the predictability of response from market to market. Hence the outcome of empirical work cannot be left to speak for itself or it will surely be misinterpreted. Instead, observed correlations or the lack thereof can only be appreciated against a background of conditional predictions derived from theory under alternative assumptions and specifications.

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