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Overnight information and intraday trading behavior: evidence from NYSE cross-listed stocks and their local market information

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Abstract

In this paper we study how overnight price movements in local markets affect the trading activity of foreign stocks on the NYSE. We find that local price movements affect not only the opening returns of foreign stocks, but also their returns in the first 30-min interval. The magnitude of local price movements is positively related to price volatility of foreign stocks, and this relation is stronger at the NYSE open and weaker afterward. This result helps explain why intraday price volatility is high at the open and lower at midday. However, local price movements cannot account for intraday variations in trading volume. We also find that trading volume for foreign stocks is strongly correlated with NYSE opening price volatility and weakly correlated with local market overnight price volatility. We interpret the result as evidence that the trading activity of foreign stocks on the NYSE is related more to liquidity trading of US investors and less to local market information.

JEL classification: G14 Information and Market Efficiency; G15 International Financial Markets

Keywords: Intraday volatility; Market microstructure; Multiple-market trading

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1. Introduction

Extensive empirical evidence documents that the stock market is more active at the beginning of the trading session. Measures of market activity, such as trading volume, price volatility, and number of transactions, are higher at the open and close for NYSE stocks (Jain and Joh (1988), Foster and Viswanathan (1993), and Jang and Lee (1993)). Several studies conjecture that the higher market activity at the open is due to overnight information that accumulates during the NYSE nontrading period. For example, Berry and Howe (1994) document that the number of news announcements released by Reuter's News Service increases at 8:00 am (EST)—one and a half hours before the NYSE open—indicating an increase in public information flow before the open. Foster and Viswanathan (1993) show that informed traders who gather private information during the nontrading period trade more aggressively after the open if they suspect their information will become public soon. Brock and Kleidon (1992) and Gerety and Mulherin (1992) argue that because of the new information that arrives during the nontrading period, the portfolio that is optimal during the previous close will no longer be optimal when the market reopens. Therefore, market activity increases immediately after the open as investors rebalance their portfolios.

In light of the relation between market activity and information flow, many authors examine internationally cross-listed stocks and check whether their price behavior is different from that of non-cross-listed stocks, given their different information-flow patterns (Barclay et al., 1990; Kleidon and Werner, 1993; Chan et al., 1994; Choe, 1994; Foster and George, 1994). Despite the intuitive appeal that the trading behavior of these cross-listed stocks in the morning is related to overnight information released in their local markets, none of these studies directly tests this possibility.

In this paper we examine the intraday patterns of trading volume and price volatility for stocks traded on the NYSE and listed on Asia-Pacific and UK exchanges. We test whether these patterns are related to public information accumulated overnight. Unlike Berry and Howe (1994) who use the number of news articles released during the nontrading period, or other researchers who use close-to-open return volatility, we infer the overnight information flow of these cross-listed stocks directly from price movements in their local markets. Since most information generated during the NYSE nontrading period about these foreign stocks is reflected in local markets, local stock price movement is a good proxy for overnight information. If the market activity at the open is related to overnight information, we expect to find a positive relation between the level of market activity in the morning and the magnitude of local stock price movement.

Furthermore, as information about these foreign stocks (both public and private) is more likely to arrive during the NYSE overnight period than during the trading period, market activity is greater in the morning than the mid-day. This suggests that once we control for the effect of overnight information (local stock price movements), intraday variations in market activity will be reduced.

Unlike previous studies, we infer overnight information from the local price movement rather than from the NYSE opening returns. Although the local price movement and NYSE opening returns are closely related, they are not perfectly correlated, as the price in one market could move because of the trading activity there. Furthermore, local trading sessions for Asia-Pacific stocks are closed before the NYSE opens. Therefore, we examine how local price movements, which are public information to US investors, affect the trading activity of foreign stocks on US exchanges.

We find that overnight price movements in local markets affect not only opening returns of foreign stocks, but also returns during the first 30 minutes. Also, the magnitude of local price movements is positively related to the price movement of foreign stocks in the morning. The relation is stronger around the open and weaker afterward. This diminishing effect of overnight information on intraday price movements helps explain why price volatility is higher at the open and lower at midday. On the other hand, local price movements cannot explain intraday variations in trading volume. This suggests that the trading volume of foreign stocks on the NYSE is not related to overnight public information. We also find that trading volume is strongly correlated with NYSE opening price movement and weakly correlated with local market price movement. We interpret this result as evidence that the trading activity of foreign stocks on the NYSE is related more to liquidity trading of US investors and less to local market information.

The paper proceeds as follows. Section 2 discusses the relation between overnight information and intraday market activity. Section 3 describes the data and summary statistics. Section 4 presents empirical methodologies and results. Section 5 presents the conclusion.

2. Relation between overnight information and intraday market activity

2.1. Why market activity is higher at the open

Extensive empirical evidence documents that stock market behavior at the beginning of the NYSE trading session differs from the rest of the day. Wood et al. (1985), Harris (1986), and Lockwood and Linn (1990) examine intraday stock returns and find that price volatility is higher near the open and close of the trading session. Jain and Joh (1988), Foster and Viswanathan (1993), and Jang and Lee (1993) find that trading volume and number of transactions are also higher at the open. Several explanations may account for this trading behavior. First, much public information accumulates overnight and is not reflected in prices during the NYSE nontrading period. Once the NYSE opens, overnight information is quickly incorporated into prices, resulting in a large price movement at the open. Berry and Howe (1994) and Mitchell and Mulherin (1994) examine the effect of public information on market activity. Using the number of news announcements released by Reuter's News Service as a measure of public information flow, Berry and Howe (1994) document that information flow substantially increases at 8:00 am (EST).

Second, informed traders gather private information during the nontrading period and may act strategically when trading with liquidity traders. This is analogous to the interday trading strategies analyzed in Foster and Viswanathan (1990). In their model, the informed trader receives private information at the beginning of the week. Since a portion of the private information is made public each day, the information becomes less valuable through time. The informed trader, knowing a public signal is forthcoming, trades more aggressively so that more information is reflected through trading. A similar logic can be applied to intraday trading. If informed traders receive private information overnight and suspect the information may be leaked later in the day, they will trade immediately after the open.

Third, volume at the close and open reflects trades made to rebalance portfolios before and after the overnight trading halt. Brock and Kleidon (1992) argue that because of overnight information, portfolios that are optimal during the previous close will no longer be optimal when the market reopens. Furthermore, portfolios that are optimal at the close can differ, because of the imminent nontrading period, from portfolios that are optimal during the continuous trading period. This inelastic demand to trade induces a surge in trading activity at the open and close.

Fourth, since the NYSE operates continuously during the trading day, but commences trading with a call auction, these two trading mechanisms could generate different transitory volatilities. Amihud and Mendelson (1987) and Stoll and Whaley (1990) document that open-to-open return variances are greater than close-to-close return variances for stocks traded on the NYSE. This implies that opening prices contain larger pricing errors than closing prices. However, subsequent studies (e.g., Amihud and Mendelson, 1991; Choe and Shin, 1993; Masulis and Ng, 1995) find similar evidence for stocks traded on other exchanges that have different trading mechanisms. This suggests that higher transitory volatility at the open is in fact due to the overnight trading halt. Without trading venues, the overnight trading halt disturbs the process of price formation until the open (Grundy and McNichols, 1989; Dow and Gorton, 1993; Leach and Madhavan, 1993). Gerety and Mulherin (1994) find that transitory volatility declines during the trading day both for the Dow Jones 65 Composite price index and for individual firms in the Dow Jones 30 index.

2.2. *A simple regression framework for understanding the effect of overnight information*

As discussed above, one reason for increased market activity at the open is that overnight information accumulates during the NYSE nontrading period. This is true even when the overnight information becomes public, since investors experience uncertainty in interpreting the information. Furthermore, as several researchers (Grundy and McNichols, 1989; Dow and Gorton, 1993; Leach and Madhavan, 1993) argue, multiple rounds of trading can produce prices that are less noisy and reveal more information than a single round of trading. Therefore, overnight information affects market activity at the open, but the effect diminishes during the day. The diminishing effect of overnight information might explain why the market activity surges at the open and declines afterward. This can be illustrated by a simple regression model. Suppose $V_{\tau,t}$ denotes intraday market activity (either trading volume or price movement) for interval τ at day t, and Φ_t denotes overnight information. If the effect of overnight information on market activity diminishes during the day, then in a set of regression equations for different intervals:

$$V_{\tau,t} = \alpha_\tau + \beta_\tau \Phi_t + \epsilon_{\tau,t} \tag{1}$$

the β_τ coefficient is larger for smaller τ. Since the average of $V_{\tau,t}$ is given by

$$\bar{V}_\tau = \alpha_\tau + \beta_\tau \bar{\Phi} \tag{2}$$

$\bar{V}_\tau$ could be higher for earlier intervals (smaller τ), even though the α_τ's are the same across all intervals. Equation (2) also suggests that if intraday variations in $V_{\tau,t}$ are only due to innovations in overnight information, the α_τ intercepts will have no variations once Φ_t is allowed to affect $V_{\tau,t}$ differently at different intervals. Note that the regression models assume that variations in market activity are solely caused by overnight information. This can be justified, especially for foreign stocks that have much information released in local markets overnight. If other variables contribute to intraday variations in market activity, the α_τ intercept will not be the same even after controlling for Φ_t.

3. Data and summary statistics

We obtain data from the NYSE Trades and Quotes (TAQ) database. It comprises all trade records and quotation records on the NYSE, AMEX, and regional exchanges. The trade records contain the time to the nearest second, date, ticker symbol, price, and number of shares traded; the quotation records contain the time, date, ticker symbol, bid and ask price, and number of shares the specialist quotes for the bid and the ask. We also obtain data from the EXTEL database, which comprises daily price records for most of the firms in the United Kingdom and large firms worldwide. The prices are in terms of foreign currencies, and are not translated into the US dollars. Therefore, the relationship between the price movement in the US and foreign market is not due to exchange rate fluctuation.

The sample period is the first quarter of 1993. Since we are examining the effect of overnight local information on NYSE trading activity, we select foreign stocks whose local trading sessions precede the NYSE. To be included in the analysis, the foreign stocks must be listed on the NYSE and have at least 20 days of more than 10 quotes a day. Each day, we match the transactions data for foreign stocks with daily stock prices in local markets. For several foreign stocks that do not have local stock prices available from EXTEL, we obtain the local data from the New York Times. Among the 29 European stocks that meet the requirements, 21 are UK. For convenience, we exclude non-UK European stocks so that the length of overlapping trading hours on the NYSE and local exchanges is the same for European stocks. Seven Asia-Pacific stocks meet our selection requirements.

Table 1 presents descriptive statistics for the final sample. Included are average daily trading volume and countries for foreign stocks. The average daily volume exhibits large cross-sectional variation across the sample, ranging from 13,013 shares for Hitachi Ltd., to more than 2 million shares for Glaxo Holding Plc. The Asia-Pacific stocks are from Japan, Hong Kong, Australia, and New Zealand, and their local trading sessions close before the NYSE opens. The European stocks are from the United Kingdom, and they trade simultaneously in London and New York for two hours. Since a portion of the price movement in London is contemopraneous with that in New York, we partition the results into samples of Asia-Pacific and UK stocks.

Table 1
Summary statistics for the sample of foreign stocks traded on the NYSE.

Obs	Ticker symbol	Company name	Country	Daily volume
Panel A: UK stocks				
1	A	Attwoods	UK	71 575
2	ASI	Automated Security Plc	UK	113 977
3	BAB	British Airways Plc	UK	87 490
4	BP	British Petroleum	UK	940 143
5	BRG	British Gas Plc	UK	26 727
6	BST	British Steel	UK	197 466
7	BTY	British Telecommunication	UK	72 451
8	CWP	Cable and Wireless Plc	UK	25 770
9	GLX	Glaxo Holdings Plc	UK	2 015 439
10	GRM	Grand Metropolitan Plc	UK	49 603
11	HAN	Hanson Plc	UK	538 483
12	HTD	Huntingdon Intl. Holdings	UK	29 654
13	SAA	Saatchi & Saatchi Co. Plc	UK	48 167
14	SBE	Smithkline Beecham Plc	UK	531 585
15	SC	"Shell" Transport and Trading	UK	101 840
16	TPH	Tiphook Plc	UK	38 782
17	UN	Unilever Plc	UK	172 279
18	VOD	Vodafone Group Plc	UK	163 511
19	WCG	Willis Corron Plc	UK	64 888
20	WEL	Wellcome Plc	UK	408 669
21	WME	Waste Management Plc	UK	116 008
Panel B: Asia-Pacific stocks				
1	HIT	Hitachi Ltd.	Japan	13 013
2	HKT	Hong Kong Telecommunication	Hong Kong	145 994
3	HMC	Honda Motor Co. Ltd.	Japan	12 000
4	NWS	News Corporation Ltd.	Australia	294 339
5	NZT	Telecommunication Corp. of New Zealand	New Zealand	75 069
6	SNE	Sony Corporation	Japan	38 592
7	WBK	Westpac Banking Corp	Australia	75 300

4. Empirical results

4.1. Relation between price movements on the NYSE and local markets

The NYSE trading session (9:30 am–4:00 pm EST) is partitioned into 14 time intervals: overnight period, open-to-10:00 am period, and twelve successive 30-min intervals. The overnight return is based on the opening transaction price of that day and the midpoint of the closing bid-ask quote of the previous day. The return for the open-to-10:00 am period is computed from the opening price to the midpoint of the last bid-ask quote of the period. The return for other 30-min intervals is computed from the midpoint of the last bid-ask quote before the end of the previous interval to the midpoint of the last bid-ask quote of the interval. Let $\mathrm{RET}^{0}_{i,t}$denotes the overnight return of foreign stock i on the NYSE at day t, and $\mathrm{RET}^{\tau}_{i,t}$denotes the return of intraday interval τ, $\tau = 1, 2, \ldots, 13$, and let $\zeta_{i,t}$ denotes the price innovation in the local market for stock i (the price information generated between the NYSE close and next day opening). The effect of local market information on intraday returns can be assessed by the regression model:

$$\mathrm{RET}^{\tau}_{i,t} = \alpha_{\tau} + \beta_{\tau}\zeta_{i,t} + \epsilon^{\tau}_{i,t} \quad \tau = 0, 1, 2, \ldots, 13 \tag{3}$$

However, the local price innovation ($\zeta_{i,t}$) is not observed. Since the data for local markets are closing stock prices, we can construct only local close-to-close returns, which reflect the price reaction to both overnight information released in the local trading session at day t and to information generated during the US trading session at day $t-1$.[1] This is demonstrated in Fig. 1. For simplicity, we assume the local trading session is closed before the US market opens, although later we see that this assumption is not important. Since local and US trading sessions do not overlap, information is reflected in the two markets at different times. Information released during the local trading session is first incorporated into prices in the local market and then into prices in the US market; the reverse is true for information released during the US trading session. In general, most of the information about foreign stocks (e.g., firm-specific and country-specific information) is released in local markets. However, since US news has global effects, information released in the US market also affects foreign stocks. As a result, local close-to-close returns reflect not only overnight information released in the home market at day t, but also information already incorporated into foreign stock prices in the US market at day $t-1$.

Therefore, the local price innovation ($\zeta_{i,t}$) could be estimated from removing prior-day US information from local close-to-close returns. Let $\mathrm{LRET}^{cc}_{i,t}$ denote local close-to-close returns at day t; let $\mathrm{RET}^{0c}_{i,t-1}$ denote open-to-close returns in the US market at day $t-1$; and, assuming a linear relation between the returns, let

$$\mathrm{LRET}^{cc}_{i,t} = a + b * \mathrm{RET}^{0c}_{i,t-1} + \zeta_{i,t} \tag{4}$$

[1] We cannot obtain opening stock prices for the stocks in their local markets, otherwise the overnight price innovation for Asian stocks could be directly inferred from the local open-to-close returns.

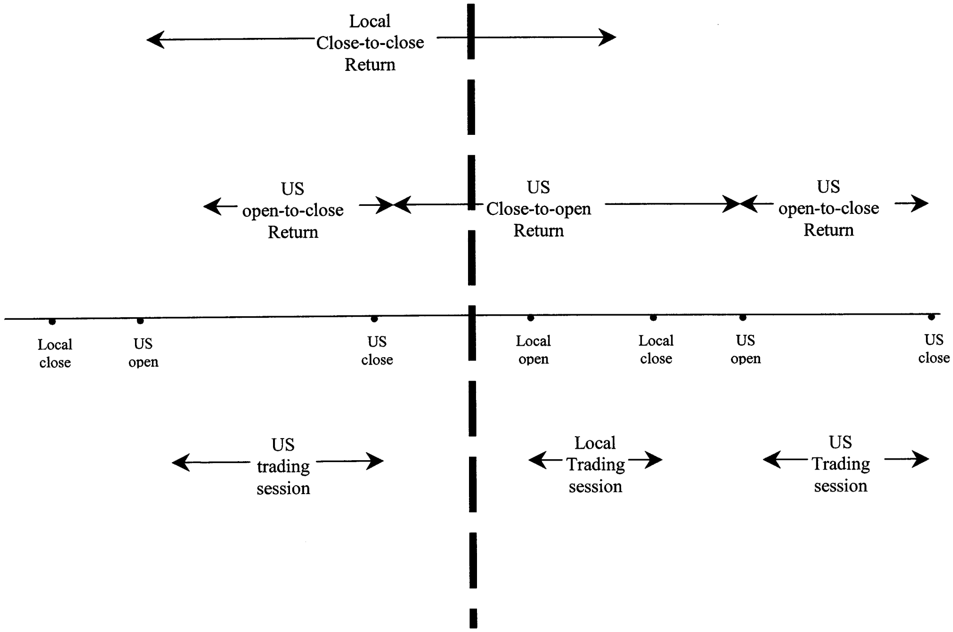

Fig. 1. Returns for foreign stocks in the Local and US markets.

Thus, local close-to-close returns at day t consist of price adjustments to: (i) US information at day $t-1$, captured by $\mathrm{RET}^{0c}_{i,t-1}$ and (ii) overnight information released in the local market at day t ($\zeta_{i,t}$). The innovations $\zeta_{i,t}$ can be captured by estimating Eq. (4) and extracting the residuals. However, instead of estimating the $\zeta_{i,t}$ innovations in Eq. (4) in the first stage and passing them to Eq. (3) for final estimation, we can obtain more efficient estimates of α_τ and β_τ through a one-step procedure. Substituting for $\zeta_{i,t}$ in Eq. (3) from Eq. (4), we obtain:

$$\begin{aligned}\mathrm{RET}^{\tau}_{i,t} &= \alpha_\tau + \beta_\tau(\mathrm{LRET}^{cc}_{i,t} - a - b*\mathrm{RET}^{0c}_{i,t-1}) + \epsilon^{\tau}_{i,t}\\ &= \alpha^*_\tau + \beta^*_\tau\mathrm{LRET}^{cc}_{i,t} + \gamma^*_\tau\mathrm{RET}^{0c}_{i,t-1} + \epsilon^{\tau}_{i,t} \end{aligned} \tag{5}$$

where $\alpha^*_\tau = \alpha_\tau - a\beta_\tau, \quad \beta^*_\tau = \beta_\tau, \quad \gamma^*_\tau = -b\beta_\tau \quad \tau = 0, 1, 2, \ldots, 13$

Therefore, β_τ coefficients can be estimated by including $\mathrm{RET}^{0c}_{i,t}$ as an explanatory variable, which is expected to have negative coefficients. The above relation is similar even when local and US trading sessions overlap. The only difference is that since some of the US information at day $t-1$ is already reflected in local market returns $\mathrm{RET}^{0c}_{i,t}$ is measured from the close of the local market to the close of the US market. Therefore, for UK stocks whose local trading sessions close two hours after the NYSE opens, $\mathrm{RET}^{0c}_{i,t}$ is measured from 11:30 am (EST) to the NYSE close.

We estimate regression coefficients subject to the constraints implied by Eq. (5). Note that although the error terms in regression equations may be correlated, there is no efficiency gain from using seemingly unrelated regression methodology since the explanatory variable is the same for each regression.

Table 2 reports regression results. The t-statistics appear in parentheses and are adjusted for heteroskedasticity using White's (1980) consistent covariance matrix. Since the estimates of β_τ are not significant for later intervals, results for intervals after 12:30 pm are not reported. As expected, the β_τ coefficient is the highest (with the largest t-statistic) for the close-to-open return. This indicates that most of the local market information is incorporated into opening prices. For Asia-Pacific stocks, estimates of β_τ are positive and significant for the open-10:00 am interval. Since Asia-Pacific markets are already closed before the NYSE opens, this suggests that not all of the local market information is incorporated into NYSE opening prices. For UK stocks, estimates of β are positive and significant up to the 10:30–11:00 am interval. This is because trading sessions in London and New York overlap for two hours.

4.2. *Market activity after controlling for the effect of overnight information*

When the NYSE opens, US investors react to overnight information, causing increases in both trading volume and price volatility. This is true even when the overnight information is public at the open, since investors experience uncertainty in interpreting the information. However, as trading proceeds, prices become less noisy, so that trading volume and price volatility decline.

Table 2
Regression of intraday returns for foreign stocks traded on the NYSE on local market returns[a].

	Asia-Pacific stocks			UK stocks		
Interval	a	β^*_τ	Adjusted R^2 (%)	a	β^*_τ	Adjusted R^2 (%)
Close-to-open		0.641 (13.27)	50.29		0.236 (3.02)	17.30
Open–10:00 am		0.104 (4.68)	7.38		0.209 (2.30)	15.25
10:00–10:30 am		0.010 (0.73)	0.05		0.027 (1.65)	1.25
10:30–11:00 am		0.003 (0.25)	−0.32		0.043 (2.17)	3.27
11:00–11:30 am		0.009 (0.79)	−0.36		−0.003 (−0.29)	−0.12
11:30–12:00 pm		0.007 (0.69)	−0.04		−0.004 (−0.68)	−0.07
12:00–12:30 pm		0.020 (2.63)	0.02		0.002 (0.37)	−0.09
	0.308 (5.04)			0.779 (10.35)		

[a] $\mathrm{RET}^\tau_{i,t} = \alpha^*_\tau + \beta^*_\tau \mathrm{LRET}^{cc}_{i,t} + \gamma^*_\tau \mathrm{RET}^{0c}_{i,t-1} + \epsilon^\tau_{i,t}$, $\tau = 0, 1, 2, \ldots, 13$; subject to the constraints: where $\alpha^*_\tau = \alpha_\tau - a\beta_\tau$, $\beta^*_\tau = \beta_\tau$, $\gamma^*_\tau = -a\beta$. $\mathrm{RET}^\tau_{i,t}$ is the intraday return for interval τ at day t, $\mathrm{LRET}^{cc}_{i,t}$ is the local market close-to-close return at day t, and $\mathrm{RET}^{0c}_{i,t-1}$ is the NYSE open-to-close return (for Asia-Pacific stocks) or 11:30 am—NYSE close return (for UK stocks) at day $t-1$. Results for intervals after 12:30 pm are not reported. The t-statistics that appear in parentheses are adjusted for heteroskedasticity using White's consistent covariance matrix of the coefficient estimates.

To examine the impacts of overnight information on market activity, we regress the intraday market activity variable ($V^{\tau}_{i,t}$) on the local market volatility ($|\zeta_{i,t}|$) for different interval τ:

$$V^{\tau}_{i,t} = \alpha_{\tau} + \beta_{\tau}|\zeta_{i,t}| + \epsilon^{\tau}_{i,t} \tag{6}$$

where $\zeta_{i,t}$ are the residuals extracted from the regression of local market close-to-close returns on NYSE open-to-close returns (for Asia-Pacific stocks) or returns from 11:30 am (EST) to the NYSE close (for UK stocks) of the prior day.[2] Intraday price volatility is measured by the absolute value of the return for the interval ($|\mathrm{RET}^{\tau}_{i,t}|$) while intraday trading volume is measured by number of shares traded during the interval ($|\mathrm{VOL}^{\tau}_{i,t}|$). Regressions are conducted using intraday price volatility and trading volume alternately as the dependent variable, and they are estimated for intervals up to 12:30 pm. In the following regressions, we combine the overnight interval and the opening interval, so that the first interval is from previous close to 10:00 am. The regressions are estimated based on pooled cross-sectional and time-series data. To control for cross-sectional variations, we normalize $|\mathrm{RET}^{\tau}_{i,t}|$ and $|\mathrm{VOL}^{\tau}_{i,t}|$ by dividing each observation by average daily price movement and daily volume for stock i, respectively.

Results for the regression of intraday price movement are reported in Table 3. We also estimate regression intercepts without admitting $|\zeta_{i,t}|$ as the explanatory variable so that we can test for intraday variations without controlling for innovations in overnight information. In Model 1 the regression excludes $|\zeta_{i,t}|$ as the explanatory variable. The regression intercepts (α_{τ}) decline monotonically during the morning, dropping from 0.782 at interval 1 to 0.093 at interval six for Asia-Pacific stocks, and from 0.704 at interval 1 to 0.133 at interval six for UK stocks. We test whether the α_{τ} coefficients are the same and reject this for both groups of stocks (p-value < 0.001). Overall, the evidence confirms previous studies that find the intraday price movement for foreign stocks traded on the NYSE is higher at the open and declines during midday.

In Model 2 the regression includes $|\zeta_{i,t}|$ as the explanatory variable. The coefficients on $|\zeta_{i,t}|$ are much higher in the first interval than in other intervals. Furthermore, for UK stocks, β_{τ} coefficients decline monotonically during the day, from 14.56 at interval 1 to -0.040 at interval six. A test of the equality of β_{τ} coefficents is conducted and rejected for both Asia-Pacific stocks (P-value < 0.001) and UK stocks (P-value $= 0.030$). The results support the hypothesis that the reaction of intraday price movement to overnight information is higher at the open and declines during the day. As expected, this helps explain intraday variations in price movement. This is confirmed by regression intercepts in Model 2. Although α_{τ} coefficients seem to differ across intervals, the variations are less pronounced. In fact, for Asia-Pacific stocks, a test of the equality of α_{τ} coefficients is not rejected at the 5% level.

[2] This follows previous studies (Stoll and Whaley (1990), Jones et al. (1994), and Huang and Masulis (1999)) that measure the price volatility based on the absolute returns.

Table 3
Regression of intraday price volatility ($|RET^{\tau}_{i,t}|$) of foreign stocks traded on the NYSE, with and without controlling for innovations in local market price volatility ($|\zeta_{i,t}|$).[a]

Interval	Asia-Pacific stocks Model 1 Intercept (α_τ)	Model 2	UK stocks Model 1 Intercept (α_τ)	Model 2
Close–10:00 am	0.782 (17.26)	0.242 (3.36)	0.704 (32.85)	0.522 (6.43)
10:00–10:30 am	0.163 (12.63)	0.137 (8.14)	0.248 (24.97)	0.215 (14.30)
10:30–11:00 am	0.137 (12.89)	0.114 (7.32)	0.194 (22.80)	0.169 (10.11)
11:00–11:30 am	0.122 (11.63)	0.091 (6.76)	0.174 (23.65)	0.154 (12.49)
11:30–12:00 pm	0.098 (10.47)	0.090 (8.29)	0.145 (20.99)	0.136 (16.95)
12:00–12:30 pm	0.093 (10.82)	0.099 (8.07)	0.133 (18.88)	0.134 (15.48)
	Beta (β_τ)	Beta (β_τ)		
Close–10:00 am		52.086 (7.03)		14.560 (2.09)
10:00–10:30 am		2.370 (1.92)		2.601 (2.55)
10:30–11:00 am		2.461 (1.93)		2.053 (1.54)
11:00–11:30 am		2.986 (2.74)		1.665 (1.73)
11:30–12:00 pm		0.989 (0.93)		0.790 (2.08)
12:00–12:30 pm		−0.571 (−0.69)		−0.040 (−0.13)
$\chi^2(\alpha_i)$	93.5 ($P<0.001$)	11.5 ($P=0.074$)	248.3 ($P<0.001$)	18.7 ($P=0.005$)
$\chi^2(\beta_i)$		26.1 ($P<0.001$)		14.0 ($P=0.030$)

[a] Model 1: $|RET^{\tau}_{i,t}| = \alpha_\tau$, and Model 2: $|RET^{\tau}_{i,t}| = \alpha_\tau + \beta_\tau|\zeta_{i,t}| + \epsilon^{\tau}_{i,t}$ $\tau = 1, 2, \ldots, 6$ where $RET^{\tau}_{i,t}$ is the intraday return for interval τ, and $|RET^{\tau}_{i,t}|$ is normalized by dividing each observation by average daily absolute returns for stock i. $|\zeta_{i,t}|$ is the absolute value of return innovations in the local market; return innovations are residuals extracted from the regression of local close-to-close return on prior-day NYSE open-to-close returns (for Asia-Pacific stocks) or 11:30 am—NYSE close return (for UK stocks). The t-statistics that appear in parentheses are adjusted for heteroskedasticity using White's consistent covariance matrix of the coefficient estimates.

Results for the regression of intraday trading volume are reported in Table 4. When the regressions are estimated without admitting $|\zeta_{i,t}|$ as an explanatory variable in Model 1, the estimates of α_τ are higher for the first several intervals. A test of whether α_τ coefficients are the same across intervals can be rejected for both Asia-Pacific and UK stocks (P-value < 0.001). When we include $|\zeta_{i,t}|$ as an explanatory variable in Model 2, the coefficients on $|\zeta_{i,t}|$ do not decline during the day. A test of the equality of β_τ coefficients cannot be rejected at the 3% level. Since overnight information does not have differential effects on trading volume during the morning, it cannot explain intraday variations in trading volume. After allowing for the explanatory power of overnight information, we can still reject that the intercepts are equal across the intervals for both groups of stocks.

Overall, evidence indicates that the reaction of intraday price movement on the NYSE to overnight information from local markets is higher at the open and declines during the midday. This explains why price movement is higher during the early morning. After we control for the effect of overnight information, intraday variations in movement are less pronounced. However, the effect of overnight information on trading volume does not decline during the day; therefore, intraday variations in volume remain unexplained.

4.3. Determinants of trading volume of foreign stocks

The theories of trading volume suggest that innovations in overnight information affect trading activity at the open. For foreign stocks, innovations in overnight information can arise from US and local markets. As the evidence in Table 2 indicates, US opening returns and local market close-to-close returns are not perfectly correlated. One reason is that the two sets of returns are not measured over exactly the same interval. Another reason is that the information to which local and US stock prices react might be different, since the information could be about liquidity trading, which is market specific. Certainly, in a perfectly integrated global market, foreign stock price movements in the US and local markets must be aligned to preclude arbitrage opportunities. However, with transaction costs, their prices could be slightly different without allowing arbitrage opportunities.

Table 4
Regression of intraday trading volume ($VOL_{i,t}^{\tau}$) of foreign stocks traded on the NYSE, with and without controlling for innovations in local market price volatility ($|\zeta_{i,t}|$).[a]

Interval	Asia-Pacific stocks Model 1 Intercept (α_τ)	Model 2	UK stocks Model 1 Intercept (α_τ)	Model 2
α_1	0.163 (13.30)	0.091 (3.87)	0.148 (23.34)	0.135 (14.10)
α_2	0.088 (8.54)	0.028 (1.41)	0.115 (16.24)	0.089 (9.50)
α_3	0.085 (8.50)	0.005 (0.13)	0.098 (13.91)	0.089 (8.63)
α_4	0.095 (9.02)	0.016 (0.52)	0.083 (10.43)	0.071 (5.35)
α_5	0.062 (10.08)	0.039 (3.19)	0.060 (16.09)	0.056 (12.22)
α_6	0.065 (8.83)	0.051 (3.19)	0.054 (6.50)	0.048 (7.28)
	Beta (β_τ)	Beta (β_τ)		
β_1		6.913 (3.22)		1.041 (1.70)
β_2		5.271 (2.71)		2.039 (3.38)
β_3		7.382 (2.00)		0.864 (1.54)
β_4		6.854 (2.20)		1.149 (0.99)
β_5		2.191 (2.00)		0.272 (1.31)
β_6		1.566 (1.22)		0.499 (1.24)
$\chi^2(\alpha_i)$	56.6 ($P<0.001$)	18.4 ($P=0.005$)	135.6 ($P<0.000$)	28.4 ($P<0.001$)
$\chi^2(\beta_i)$		8.9 ($P=0.179$)		13.4($P=0.037$)

[a] Model 1: $VOL_{i,t}^{\tau}=\alpha_\tau$ and Model 2: $VOL_{i,t}^{\tau}=\alpha_\tau+\beta_\tau|\zeta_{i,t}|+\epsilon_{i,t}^{\tau}$, $\tau=1, 2, \ldots, 6$, where $VOL_{i,t}^{\tau}$ is the intraday trading volume for interval τ at day t, and is normalized by dividing each observation by average daily volume for stock i. $|\zeta_{i,t}|$ is the absolute value of return innovations in local markets; return innovations are residuals extracted from the regression of local close-to-close returns on prior-day NYSE open-to-close returns (for Asia-Pacific stocks) or 11:30 am—NYSE close returns (for UK stocks). The t-statistics that appear in parentheses are adjusted for heteroskedasticity using White's consistent covariance matrix of the coefficient estimates.

Table 5
Regression of intraday trading volume ($VOL^{\tau}_{i,t}$) of foreign stocks traded on the NYSE on innovations in local market price volatility ($|\zeta_{i,t}|$) and opening price volatility ($|RET^{0}_{i,t}|$).[a]

	Asia-Pacific stocks			UK stocks		
Interval	β_i	γ_i	Adjusted R^2 (%)	β_I	γ_i	Adjusted R^2 (%)
Close–10:00 am	2.019 (1.84)	5.172 (3.89)	8.89	0.727 (1.30)	2.428 (3.15)	1.58
10:00–10:30 am	1.431 (1.70)	3.362 (2.05)	3.60	1.612 (3.30)	3.400 (3.34)	3.43
10:30–11:00 am	1.446 (1.57)	3.229 (2.77)	5.89	0.633 (1.12)	1.601 (1.71)	0.40
11:00–11:30 am	1.317 (0.76)	3.771 (2.69)	6.46	1.262 (0.93)	−0.904 (−0.63)	0.37
11:30–12:00 pm	0.246 (0.40)	1.434 (1.48)	0.99	0.297 (1.34)	−0.010 (−0.02)	−0.00
12:00–12:30 pm	−0.743 (−0.84)	2.153 (2.55)	0.63	0.497 (1.23)	0.204 (0.35)	−0.09
χ^2 (β_i)	6.5 ($P=0.370$)			12.1 ($P=0.062$)		
χ^2 (γ_i)		15.7 ($P=0.015$)			15.5 ($P=0.017$)	

[a] $VOL^{\tau}_{i,t}=\alpha_\tau+\beta_\tau|\zeta_{i,t}|+\gamma_\tau|RET^{0}_{i,t}|+\epsilon^{\tau}_{i,t}$ $\tau=1, 2, \ldots, 6$, where $VOL^{\tau}_{i,t}$ is the intraday trading volume on the NYSE, $RET^{0}_{i,t}$ is the return measured from close to open, and both $VOL^{\tau}_{i,t}$ and $|RET^{\tau}_{i,t}|$ are normalized by dividing each observation by average daily volume and absolute daily returns for stock i, respectively. $|\zeta_{i,t}|$ is the absolute value of return innovations in local markets; return innovations are the residuals extracted from regression of local market close-to-close return on prior-day NYSE open-to-close return (for Asia-Pacific stocks) or 11:30 am—close NYSE return (for UK stocks). The t-statistics that appear in parentheses are adjusted for heteroskedasticity using White's consistent covariance matrix of the coefficient estimates.

Given that information in the two markets might be different, we examine how the trading activity of foreign stocks reacts to either source of information. This is related to the literature on the relation between volume and price variability (see Karpoff (1987) and Gallant et al. (1992)). We extend the analysis by examining whether trading volume on the NYSE is correlated more with overnight price variability from the US or local markets. Price variability is measured by the absolute value of the return, and a regression model for trading volume is estimated for each of the first six intervals:

$$VOL^{\tau}_{i,t}=\alpha_\tau+\beta_\tau|\zeta_{i,t}|+\gamma_\tau|RET^{0}_{i,t}|+\epsilon^{\tau}_{i,t} \quad \tau=1, 2, \ldots, 6 \tag{7}$$

Similar to previous regressions, the overnight interval is merged with the opening interval; therefore, $VOL^{l}_{i,t}$ is the volume from the opening and the first 30-min interval. $VOL^{l}_{i,t}$ is again normalized by dividing each observation by the average daily share traded for stock i.

Table 5 reports the results. Most of the coefficients associated with innovations in local price volatility ($|\zeta_{i,t}|$) are not significant for either Asia-Pacific or UK stocks, and a χ^2 test fails to reject the hypothesis that the β_τ coefficients are jointly equal to zero. On the other hand, the coefficients associated with opening price volatility at the NYSE ($|\mathrm{RET}^0_{i,t}|$) are generally positive and significant, and a χ^2 test rejects the hypothesis that the γ_τ coefficients are jointly equal to zero (P-value = 0.015 for Asia-Pacific stocks, P-value = 0.017 for UK stocks). Overall, results indicate that the trading volume for foreign stocks on the NYSE is related to opening price volatility and not local price volatility. Since opening price volatility represents the incremental information in the US over local price volatility, it likely reflects information about US investor trading activity. Therefore, our evidence suggests that trading activity of foreign stocks is affected more by liquidity trading of US investors than by local market information.

5. Conclusion

We examine trading volume and price volatility for foreign stocks traded on the NYSE. We find that local price movements affect not only opening returns of foreign stocks, but also returns in the first 30 min. This suggests that not all local market information is incorporated into opening prices.

The magnitude of local price movements is positively related to price variability of foreign stocks, and this relation is stronger at the NYSE open and weaker afterward. This result helps explain why intraday price volatility is higher at the open and lower at midday. However, local price movements cannot account for intraday variations in trading volume. We also find that trading volume for foreign stocks is strongly correlated with the NYSE opening price volatility and weakly correlated with local market overnight price volatility. Therefore, our evidence suggests that the trading activity of foreign stocks is affected more by liquidity trading of US investors and less by local market information.

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