HOW INFORMATION TRANSMITS TO EQUITY MARKETS: EARNINGS ANNOUNCEMENTS AND VOLATILITY

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ABSTRACT

We explore the impact of earnings announcements on equity markets, using intraday price data for the DJIA stocks. We find on a daily basis, an abnormally high volatility only within one day following the overnight announcement. On an intraday basis, a striking volatility spike stands out during the overnight period, implying that the earnings news is fully reflected in the opening price. The continued high volatility during the first several minutes of trading seems to be driven by noise traders, given the one-minute returns uncorrelated with the overnight return. Using the standardized earnings surprise (SES), we find the overnight return highly dependent on good and bad news and no relationship between the 9:30-9:31 return and news content. The evidence along with the CAAR patterns surrounding the earnings announcement confirms that the equity market is completely awake and busy in reflecting the new information in the opening trading price.

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We explore the impact of earnings announcements on equity markets. It is widely perceived that earnings announcements have a major impact on stock prices at the level of individual stocks. In fact, numerous studies, such as Chordia and Shivakumar (2006), Jackson and Johnson (2006), and Vega (2006) among others, have dealt with the issue of post-earnings-announcement drift (PEAD), where the impact is shown to persist over days, weeks, and even quarters.[1] PEAD is described by Fama (1998) as a long lasting stock market anomaly that turns out robust with numerous studies including Bernard and Thomas (1990), and remains an open puzzle.

If the market has become much more efficient at processing information in the last several decades since Ball and Brown (1968) first found out PEAD, it is worth investigating the impact of earnings announcements using more detailed data rather than daily, weekly, or quarterly data. With the exception of Patell and Wolfson (1984) and Woodruff and Senchack (1988), however, the impact of earnings announcements on an *intraday* basis has received scant attention.[2] This is doubly surprising given that the extremely sensitive and quick reaction of the market to any relatively small earnings surprise is frequently observed, and that the stock price adjustment to earnings announcements would take place only within a day.[3]

Consistent with previous findings, as shown in Figure 1, stock prices are much more

[1] Other recent studies in this area include Garfinkel and Sokobin (2006), Kothari et al. (2006), Livnat and Mendenhall (2006), Sadka (2006), and Shin (2006).

[2] Patell and Wolfson (1984) show that following earnings and dividend announcements, trading profits disappear within five to ten minutes and that high volatility persists even into the next day. Woodruff and Senchack (1988) find that the 67%-91% of the price adjustment following earnings announcements occurs within three hours of the announcement.

[3] For example, Intel announced its earnings on October 15, 2002 after the market closed and its stock fell 19.89% on the next day. Analysts had expected the company to earn 13 cents per share in the third quarter, but the company reported earnings of 10 cents per share. In contrast, outperforming analyst expectations can lead to sharp increases in the stock price. Before the market opened on April 23, 2003, AT&T announced earnings of 67 cents a share. The company's earnings exceeded analyst estimates of 52 cents a share and the stock price increased by 20.84%.

volatile on the days of earnings announcements. The daily return standard deviation on the announcement day is over two and a half times the standard deviation on the counterpart control days. Also, there is no difference in volatility between announcement and control periods during the five days prior to the earnings announcement. During the five days following the announcement, the standard deviation tends to be only slightly higher for the announcement period than for the control period. So it is very clear that the considerably high volatility caused by earnings announcements is mostly concentrated within one day.

We examine the impact of the quarterly earnings announcements of the component stocks of the Dow Jones Industrial Average (DJIA), listed in the Appendix, on intraday volatility. The dates and times of the earnings announcements were found by searching for the first mention of the announcement by three newswire services – Dow Jones News Service, PR Newswire, and Reuters News.[4] We find that most of the firms announce their quarterly earnings after the market closes or before it opens, or as depicted in Figure 2 between 16:00 and 9:30, which is consistent with the findings of Berkman and Truong (2009).[5] We call these announcements *overnight* announcements. We use intraday stock prices from the New York Stock Exchange (NYSE) Trade-and-Quote (TAQ) database acquired via Wharton Research Data Services (WRDS) for the DJIA component stocks. We focus on close-to-open, five-minute, and minute-by-minute returns to see the impact of overnight announcements for the test period covering from January 2, 2002 through December 31, 2006.

[4] The three newswire services generally report the earnings announcements within a few minutes of one another. For example, GE made an earnings announcement before the market opened on October 13, 2006. The first mention of the earnings announcement by Dow Jones News Service, Business Wire, and Reuters News came at 6:30 a.m., 6:30 a.m., and 6:33 a.m., respectively. However, since we do not analyze intraday announcements and use only the announcements that occur after the market closes or before it opens, these small discrepancies have no effect on the results.

[5] Out of 520 quarterly earnings announcements, we have 490 after-hours (both after-close and pre-open) announcements, which is approximately 94%, in contrast to Woodruff and Senchak (1988) where about 27% of their sample are after-hours announcements. Berkman and Truong (2009) consider the announcements made only after the market closes, not before it opens, as their after-hours announcements, and still show the proportion has substantially increased over time to more than 40%.

We compare daily return volatilities between announcement days and control days, and find that an abnormally higher than normal volatility is observable only within one day following the announcement. Given this result, we feel encouraged to move on with five-minute returns for an intraday analysis. A clear picture emerging from our investigation is the unrivaled *volatility spike* that occurs between the market close before the announcement to the market open following the announcement. The second highest volatility is observed for the first five minutes of trading. Using more detailed minute-by-minute returns, we find that the big overnight volatility jump is followed by relatively high volatilities for about four minutes after the market open. However, somewhat surprisingly, the one-minute returns with high volatilities are independent of the close-to-open return. Is the price movement after the market open then due to noisy trading?[6] Or maybe it reflects the new information, and instead the overnight price movement is noisy.

We adopt the standardized earnings surprise (SES) as a measure of good and bad news and try to answer the question of whether or not the stock price responds to earnings news that is released overnight. We find the overnight return contingent upon good or bad news and no correlation between news content and the 9:30-9:31 return. We also examine the cumulative average adjusted returns (CAARs) in our analysis of minute-by-minute returns from 15:55 (5 minutes prior to the market close) to 9:35 (5 minutes after the market open), and reinforce our earlier findings of the nearly complete price adjustment to new information during the overnight period with negligible information leakage and a very small amount of further price adjustment for several minutes following the market open.

The remainder of the paper is organized as follows. In Section I, we describe our data

[6] Noisy trading refers to the trading mostly done by uninformed "noise" traders. Some informed traders, however, with different opinions on the margin may also partly contribute to noisy trading. So any trading that is completely independent of news contents and hence does not reveal new information is considered noisy.

set, and define announcement and control periods. In Section II, we examine the impact of earnings announcements, and report the daily and intraday return volatilities in response to the announcements. In Section III, we determine how quickly the earnings announcements transmit to the equity markets. Market efficiency along with information leakage is also explored in the context of the information transmission process. In Section IV, attention is turned to news content via the standardized earnings surprises (SES), and the differential impact of good and bad news on the market is analyzed. We attempt to measure the magnitude of the price adjustment to new information with minute-by-minute AARs and CAARs in Section V, and Section VI concludes the paper.

I. Data

Our data consist of (1) the dates and times of earnings announcements for component firms of the DJIA for the January 2002 – December 2006 period, (2) the stock price returns of those firms around the earnings announcements, and (3) the stock price returns for control periods in which earnings announcements were not made.

A. Earnings Announcement Data

We include only those firms that were DJIA components for the entire sample period from 2002 through 2006. AIG, Pfizer, and Verizon replaced AT&T, Eastman Kodak, and International Paper in the DJIA on April 8, 2004 so these are eliminated from the sample. SBC Communications, a DJIA component firm, merged with AT&T on November 21, 2005 and changed its name to AT&T Incorporated. Because of the merger, we also exclude SBC from the sample. This leaves 26 firms that were in the DJIA from 2002 to 2006, and they are listed in the Appendix. To avoid comparing announcements made during the trading day with announcements made while the market is closed, the intraday announcements are eliminated

from our sample. For the 26 DJIA stocks listed in the Appendix, this eliminates 19 earnings announcement for American Express, 4 for Altria, 5 for IBM, and 2 for Walt Disney. Thus, there were a total of 490 (=26x20-30) earnings announcements, 109 after-close and 381 pre-open, for the DJIA stocks during the test period. Out of 109 announcements between 16:00 and 24:00, 104 announcements were concentrated during 16:00-16:30, and 5 announcements were during 16:30-17:30. Also, out of 381 announcements between 0:00 and 9:30, 375 announcements were clustered during 6:00-9:00.[7]

B. Stock Return Data for Earnings Announcement Days

The stock return data are based on prices from NYSE's TAQ database acquired via WRDS for the DJIA stocks. The price variable is WRDS's "Actual Trade Price per Share." The prices are filtered by timestamp beginning at 9:30:00 and ending at 16:00:00 to eliminate trades made outside of the regular trading session.

The announcement day is defined as the first trading day in which the earnings announcement becomes available to market participants. For announcements made in the morning before trading begins, the announcement day is the same day. For announcements made after the market closes, the announcement day is the next trading day.[8] For daily returns, the return data consist of an 11-day window that includes the returns on the five trading days prior to the announcement, the announcement day, and the five days following the announcement. Daily returns are calculated as the log differences of the closing prices with the closing price defined as the price of the last trade through 16:00:00.

For the intraday returns, the return data consist of the return from the closing price on

[7] Specifically, 93, 182, and 100 announcements were clustered during 6:00-7:00, 7:00-8:00, and 8:00-9:00, respectively, and only 4 and 2 announcements were during 0:00-6:00 and 9:00-9:30.

[8] Our approach is consistent with Berkman and Truong (2009). They show why it is important for event studies to use the following day as Event Day 0 if the earnings announcement is made after the market closes. Specifically, daily returns, volume, and volatility are significantly biased if the announcement date is used for Event Day 0 when the day after the announcement should be Day 0.

the trading day preceding the announcement day to the opening price on the announcement day, and then the returns in five-minute intervals from the opening price on the announcement day until the closing price on the announcement day. The closing price for the day preceding the announcement is the last trade made at or before16:00:00. The opening price on the day of the announcement is the first price listed at or after 9:30:00. The price for the end of the first five-minute interval is the price of the last trade at 9:35:00 or earlier. The closing prices for subsequent five-minute intervals are defined in the same way.[9] The five-minute returns are calculated as the log differences of the prices at the end of the five-minute intervals. Thus, for each announcement day, there is one close-to-open return and 78 five-minute returns for a total of 79 observations. Figure 2 illustrates how the close-to-open return and the return for the first two five-minute intervals are determined.

C. Stock Return Data for the Control Period

For the daily data, the control period includes daily returns for 11 days centered on the day four weeks before the announcement and the day four weeks after the announcement. Similarly, the control sample for the intraday returns consists of intraday returns on the day four weeks before the announcement and the day four weeks after the announcement. The four week intervals mean that the control period has the same days of the week as the announcement period, which eliminates any day-of-the-week effects. If the day four weeks before or after the announcement day is a holiday, the day three weeks before or after the announcement day is used to determine the control period.[10]

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[9] There were some exceptions. For AA, on September 13, 2006, TAQ lists the price as $27.96 at 14:09:55, $28.95 at 14:09:57, and $27.97 at 14:10:03. Except for that one observation, the max price on 9/12/2006 is $28.08. We assume the $28.95 price is a mistake and use the 14:10:03 price as the end of the 14:05-14:10 interval. Also, for BA, the prices on April 21, 2004 include: 11:49:47 $40.88, 11:49:50 $33.35, 11:50:06 $40.91. The price stays above $40 all day and the $33.35 is the only exception. So, we use the 11:50:06 $40.91 to close that one-minute interval.

[10] Of the 980 control days, there were 25 control days in which the day four weeks before the announcement was a holiday and 18 control days in which the day four weeks after the announcement was a holiday. Thus, there are 43 control days that are not four weeks before or after the announcement

II. Daily and Intraday Volatilities

A. Daily Return Volatility

Our volatility measure is the standard deviation of returns. Daily log returns, $\ln(P_t / P_{t-1})$, are first calculated from prices of the DJIA stocks for the 11-day window (day-5 through day+5) surrounding each quarterly earnings announcement, where day0 is the announcement day. As mentioned above, there were a total of 490 announcements, and therefore the standard deviation of these 490 daily log returns for day0 is calculated as the announcement day volatility. Similarly, we calculate ten more standard deviations for day-5 through day+5, and the results are shown in Figure 1 as *solid* bars. It is readily apparent that returns are much more volatile on the announcement day than on other days in the 11-day window. We conduct the Brown-Forsythe-modified Levene (B-F-L) test for the null hypothesis that the variance of returns is constant across the 11 daily intervals (day-5 through day+5).[11] The homoskedasticity null is rejected at the 0.01 percent level with the F statistic of 51.77. This result would mainly be due to the sharp increase in volatility on the announcement day.

If there were no announcement, would variance remain fairly constant over the 11-day window? To answer this question, we examine daily return volatilities for the control period that are four weeks before and after the announcement day. While there were 490 return

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day. Also, MSFT's stock split on February 14, 2003, effective February 18, so the control days after the earnings announcement include the split. To avoid possible effects of the split, the control days after the announcement are centered on the day two weeks after the announcement.

[11] Conover, Johnson, and Johnson (1981) compare over fifty methods of testing for homogeneity of variance and find that this test is among the most powerful and is robust to nonnormality. It is used by Lockwook and Linn (1990) to test for homogeneity of intraday return variances. For example, the Brown-Forsythe-modified Levene test statistic for homoskedasticity across the 11 daily intervals is

$$F = \frac{\sum_{j=1}^{J} n_j (\overline{D}_{\bullet j} - \overline{D}_{\bullet\bullet})^2 (N-J)}{\sum_{j=1}^{J}\sum_{t=1}^{n_j} (D_{tj} - \overline{D}_{\bullet j})^2} \frac{(N-J)}{(J-1)}$$

where $D_{tj} = \left| r_{tj} - \hat{M}_j \right|$; r_{tj} is the return for announcement period t, interval j; $\hat{M}_j$ is the sample median return for interval j computed over the n_j periods included in the test; $\overline{D}_{\bullet j} = \sum_{t=1}^{n_j} (D_{tj} / n_j)$ is the mean absolute deviation from the median for interval j; and $\overline{D}_{\bullet\bullet} = \sum_{j=1}^{J}\sum_{t=1}^{n_j} (D_{tj} / N)$ is the grand mean, and $N = \sum_{j=1}^{J} n_j$. The statistic is distributed $F_{J-1,N-J}$ under the null hypothesis.

observations for the announcement day, we have 980(=490x2) observations for the corresponding control days (2 control days per 1 announcement day). Standard deviations for the control period are calculated and contrasted with those for the announcement period as shown in Table I. They are also denoted as *open* bars in Figure 1. The F statistic for the null of constant variance across daily intervals for the control period is sharply reduced to 0.4138, which is not statistically significant. This reassures that the heteroskedasticity for the announcement period can be attributed to the volatility spike on the announcement day.

In Table I, of particular interest is the announcement day volatility (3.954%) that is more than two and a half times the control day volatility (1.551%). The F statistic for the null of equality between the two volatilities is 300.35, which is significant at the 0.01 percent level. However, for day-5 through day-1 in Figure 1, there seems no difference in daily return volatilities between the announcement and control periods, and the F statistic for each daily interval indeed turns out to be mostly insignificant. As shown in Table I, the ratio of the announcement period standard deviation to the control period standard deviation for day-5 through day-1 is greater than one for four days and less than one for 1 day, and they are all insignificant. Even one day prior to the announcement day, the standard deviation ratio is 1.06, or close to 1, which suggests that the market does not seem to react before the announcement. For day+1 through day+5, as shown in Figure 1 and Table I the announcement period tends to have higher volatility than the control period. The standard deviation ratio is greater than one for four days, and significant on day+3 at the 2% level. However, compared to the announcement day (day0), the difference in variance remarkably decreases,[12] implying that the higher than normal volatility caused by earnings announcements is concentrated on the announcement day

[12] The standard deviation ratio decreases from 2.60 on day0 to 1.15 on the average for day+1 through day+5.

and does not spill much into the subsequent days.[13]

B. Intraday Return Volatility

As is seen from Figure 1 and the B-F-L tests for equality of variance between the announcement and control periods, the volatility adjustment to earnings announcements appears to occur largely within a day. We now examine intraday volatility patterns in response to earnings announcements. We calculate log returns for a total of 78 five-minute intervals (9:30 through 16:00) over the trading day as well as the previous close-to-open log return for each earnings announcement. We also examine 78 five-minute returns on the day before the announcement. Both the announcement and control period standard deviations are shown in Figure 3 as *solid* and *dashed* lines, respectively, from the day before each overnight earnings announcement of the DJIA underlying stocks to the day following the announcement. The time on the horizontal axis indicates the end of the interval in Eastern Time, e.g., 10:00 for the 9:55 to 10:00 interval, with an exception of 9:30 for the previous close-to-open interval.

As shown in Figure 3, there is an astounding "volatility spike" from the market close on day-1 to the market open on day0. Since the previous close-to-open return interval (16 hours and 30 minutes) consists of 210 five-minute intervals, it is somewhat natural to observe relatively higher volatility during the overnight period. In fact, the close-to-open standard deviation on day-1 is approximately 4.3 times and 3.9 times the average 5-minute standard deviation for the announcement and control samples, respectively, on day-1. However, the ratio of the announcement close-to-open standard deviation to the control close-to-open standard deviation, which is more interesting to us, is only 1.32 (=0.008364/0.006329) on day-1. And this ratio dramatically increases to 4.62 (=0.027430/0.005941) on day0, the announcement day. As

[13] Patell and Wolfson (1984) and Jennings and Starks (1985) observe that following earnings and dividend announcements, the equity return variance remains higher than normal for several hours and even into the next day.

pointed out by Vives (1995) and Biais et al. (1999), any information on the earnings announcement made from the previous close to the open must have been reflected in the opening price and the close-to-open return standard deviation as well.

We now focus on intraday volatility patterns on day0. It is evident that returns are much more volatile over the 9:30 to 9:35 interval, or the first five-minute interval of the day, than any other five-minute interval. The ratio of the 9:30 to 9:35 standard deviation to the next highest five-minute (9:35 to 9:40) standard deviation is 2.03 (=0.017094/0.008423). Figure 3 shows that, while the 9:30-9:35 standard deviation is still the highest among the control 5-minute volatilities on day0, the size is substantially reduced from 0.017094 (announcement) to 0.006998 (control). The close-to-open standard deviation also decreases from 0.027430 (announcement) to 0.005941 (control).[14] These results suggest that without earnings announcements, the volatility spike and the following elevated volatility virtually disappear.

In Figure 3, for the announcement set, there is a sharp decline in volatility from the first to the second five-minute interval on day0, although for the first 30 minutes volatility tends to be relatively higher than the rest of the day. Also, compared to the control set, volatility on the announcement day appears to be higher for about two hours in the morning.[15] However, for the remaining intervals, there seems no clear distinction in volatility between the announcement and control days.

[14] Amihud and Mendelson (1987) and Stoll and Whaley (1990) show that opening prices are noisy and induce excessive volatility due to the lack of an explicit information adjustment mechanism at the NYSE. Our evidence suggests that the close-to-open volatility remains the highest following an overnight earnings announcement. We believe the abnormally high opening volatility on the announcement day is due to information revelation in addition to the effect of noise trading.

[15] Note that on the day before announcements (day-1), this kind of volatility pattern is not observable. Throughout the whole day, the announcement volatilities are slightly higher than the control volatilities quite consistently.

III. The Speed of Information Transmission and Market Efficiency

A. Volatility Persistence

Attention is now turned to the question of how quickly the stock prices adjust to earnings announcements. As hinted in Figure 3, the standard deviation of returns appears to increase abruptly when the new information arrives during the overnight period and continue to remain high particularly for the first five minutes. We expect the standard deviation to return to normal when the equity market reflects completely all the information and implications of the announcement. We determine how long it takes for the earnings information to fully transmit to the equity market by measuring how long return volatility remains higher than normal through the trading day.

In Table II, we report five-minute return standard deviations on the announcement day and on the counterpart control days (four weeks before and after the announcement day). Five-minute standard deviations are reported successively from 9:30 to 10:30 and at thirty-minute intervals from 10:30 to 16:00. The ratio of these two standard deviations and the Brown-Forsythe-modified Levene test statistics for equality between the announcement and control days are also reported. As already shown in Figure 3, the 9:30 to 9:35 standard deviation is over 2.4 times as high on the announcement day as on the control days. The announcement-day standard deviation declines quite rapidly for the next five minutes although it still remains substantially higher than the control-day standard deviation. From 9:30 through 10:30, the announcement-day standard deviation is significantly higher than the control-day standard deviation at the 0.01 percent level. Over the remaining 66 five-minute intervals (10:30-16:00), the standard deviation ratio is either significant or insignificant, but generally tends to exceed one. Of the 66 ratios, 65 ratios exceed 1.0, and 50 ratios are significant at the 0.05 percent level. To summarize, volatility is abnormally high for the first five minutes, sharply decreases for the

next five minutes, remains higher than normal for 50 more minutes, and then continues to remain slightly higher for the rest of the day.

B. The Speed of Information Transmission

We now seek further evidence of the volatility adjustment to earnings announcements during the first thirty minutes of trading, using minute-by-minute returns. We estimate a regression in which the dependent variable is the absolute value of the difference between the actual return R_{jt} for one-minute interval j on day t and the mean return R_j for interval j over all announcement and control days. Dummy variable D_t is defined to be 1 if the earnings announcement is released prior to the market open on day t and zero otherwise. The regression format is

$$\left|R_{jt} - \overline{R}_j\right| = a_{0j} + a_{1j} D_t + e_{jt} \qquad (1)$$

Schwert (1989) and Schwert and Seguin (1990) show that for normally distributed log returns with constant mean but time-varying variance, $E\left|R_{jt} - \overline{R}_j\right| = \sqrt{2/\pi}\sigma_{jt} = a_{0j}$ where σ_{jt} is the standard deviation of returns in interval j on day t. An estimate of the standard deviation of returns in interval j would be $\sqrt{\pi/2}a_{0j}$ and $\sqrt{\pi/2}(a_{0j} + a_{1j})$ on control days and on announcement days, respectively. If an earnings announcement does not impact the equity market during interval j, a_{1j} should be approximately zero.

The regression is estimated for each 1-minute interval during thirty minutes following the market open, i.e., from 9:30 through 10:00. Out of 490 announcement days, no trades were recorded in the TAQ database during the 9:30-9:31 interval for 162 days. By excluding those days from the sample, the announcement day sample size was reduced from 490 to 328 (=490-162). The control day sample size was also reduced from 980 to 719 since no trades were recorded during the 9:30-9:31 interval.

Results are shown in Table III. On announcement days, the estimated standard deviation of the 9:30-9:31 returns is $\sqrt{\pi/2}(1.13+1.73)(10^{-3})$ while it is only $\sqrt{\pi/2}(1.13)(10^{-3})$ on control days. The announcement-day standard deviation of 9:30-9:31 returns averages 2.5 times the control day standard deviation. This ratio is 2.1, 1.7, 2.0, 1.6, 1.7, 1.7, 1.8, 1.6, and 1.5 for the consecutive nine minutes, i.e., 9:31-9:32 through 9:39-9:40. For the 9:40-10:00 period, the ratio remains fairly constant around 1.5. It is notable that the major volatility adjustment to earnings announcements is complete only within four minutes after the market open, or 9:30-9:31 through 9:33-9:34, although the adjustment still continues. In particular, the biggest impact of announcements occurs during the first one minute of trading, followed by the second biggest impact during 9:31-9:32.

Our evidence on how rapidly the equity markets adjust to earnings announcements is quite impressive. Since announcements are made between the previous day market close and the market open, new information must have been reflected in the opening price, and thus in the previous close to open returns. We expect further adjustment at the opening period of trading. Using minute-by-minute returns, within the first five minutes, the first two minutes exhibit the greatest impact of announcements, and the major adjustment is almost complete at the end of four minutes. Compared to Woodruff and Senchak (1988), we find a much faster adjustment of stock prices to earnings announcements. In their paper, they find the first trade is within 14 minutes of the earnings announcement for most stocks. In our paper, most of the price and volatility adjustment is complete within that period.

C. Market Efficiency

We now address the issue of market efficiency. If the market reacts slowly to the new information, excess returns may be earned based on the initial market response. Specifically, we determine if it is possible to make excess profits by observing the initial price response and

buying (selling) if the initial return is positive (negative). We use the previous day close (16:00) to the market open (9:30) return as the initial return. Given the rapid market adjustment, we focus on minute-by-minute returns for our analysis.

As mentioned in Section II.B above, we hypothesize that new information on earnings is initially reflected in the opening price and the close-to-open return. If several more minutes are required for the price to reach its new equilibrium level after the market open, returns in successive minutes would tend to be positively correlated. Once the adjustment is complete, this correlation should disappear. In the previous section, we showed that the major market adjustment takes the first four minutes of trading and that the mild adjustment continues. Using minute-by-minute returns from 9:30 to 9:35, we determine whether these returns are a continuation of the close-to-open market adjustment or independent adjustments due to a refinement of the original information. If the former, a trader may be able to execute a trade quickly to make profits by observing the close-to-open return.

Correlation matrices are shown in Panel A of Table IV for the close-to-open and the first five-minute period. Consider the correlation between the close-to-open return and the first minute return, i.e., 16:00-9:30 and 9:30-9:31. There is no evidence that the price adjustment initiated during 16:00-9:30 continues into the first minute of trading. The correlation turns out zero, implying the price movement between 9:30 and 9:31 is completely independent of the close-to-open price adjustment. Similarly, the correlations between the close-to-open return and the successive one-minute returns are all not significantly different from zero. For example, when the price rises during 16:00-9:30, probably due to some good information on earnings, we may naturally expect that the price continues to rise during 9:30-9:31. Contrary to our expectation, the price either rises or declines during 9:30-9:31, 9:31-9:32, and so on.

Our results suggest that new information on earnings is *fully* reflected in the opening

(9:30) price without entailing further price adjustments in successive minutes. While the complete price adjustment is made between 16:00 and 9:30, we reported in the previous section that prices continue to be abnormally volatile until 9:34. This continued volatility must have been induced by those traders who tend to react slowly to earnings announcements. They either have no immediate access to the equity market or want to wait and have a better understanding of the implication of the original information that becomes clear through trading in the market. In any case, one-minute returns from 9:30 to 9:35 are independent of the 16:00-9:30 initial return, implying that the market is efficient in the sense that no trading profits can be earned by those with immediate market access. The abnormally high volatility during the first four minutes seems to be due to an independent information flow. Note that the correlations between the 9:30-9:31 return and one-minute returns from 9:31 to 9:35 are also inconsequential, except the 9:31-9:32 interval where the correlation is significantly negative at the 5 percent level. This implies a possible *mild* overreaction of the market between 9:30 and 9:31 that is corrected between 9:31 and 9:32.

D. Information Leakage

To address the information leakage issue, we compute correlation coefficients between the close-to-open return and one-minute returns during the last five minutes of trading on the day prior to earnings announcements. The results are shown in Panel B of Table IV. While there is no correlation between the 15:59-16:00 return and the 16:00-9:30 return, there is evidence of other positive correlations. Specifically, the 15:58-15:59 return is significantly correlated with 16:00-9:30 return at the 1 percent level. Also, the correlation between the 15:57-15:58 return and the 15:59-16:00 is significantly positive at the 1 percent level. Information seems to leak about two or sometimes three minutes prior to the market close, and more refined investigation is warranted.

IV. Earnings Surprises – Good News and Bad News

A. Standardized Earnings Surprise (SES)

In the previous section, we showed that new information on earnings is fully reflected in the opening price and that the uncorrelated 9:30-9:31 return is noisy. However, the close-to-open return may be noisy, in the sense that its high volatility may not be due to the *informed* reflection of news. The high volatility with the price movement between 9:30 and 9:31 may indeed begin to reflect the content of new information. To address this issue, we introduce the standardized earnings surprise (SES) as a measure of whether a given announcement is good or bad.[16] Good and bad news should entail positive and negative returns, respectively. Our question is which exhibits the informed reaction to news between the close-to-open return and the 9:30-9:31 return. The SES is defined as follows:

$$SES_{jt} = \frac{(AE_{jt} - EE_{jt})}{P_{jt}} \qquad (2)$$

where SES_{jt} = standardized earnings surprise for firm j on announcement day t

AE_{jt} = actual earnings for firm j on announcement day t

EE_{jt} = mean expected earnings for firm j on announcement day t

P_{jt} = the closing stock price for firm j on announcement day t

The mean expected earnings, EE_{jt}, are based on I/B/E/S analyst estimates in the 30 calendar days before the earnings announcement. If an analyst makes more than one estimate, the latest one is used. For some earnings announcements, there are no estimates within 30 days of the announcement and those observations are excluded.

[16] Most papers on post-earnings-announcement drift refer to the earnings surprise as SUE, which stands for standardized unexpected earnings. Usually, e.g. Bernard and Thomas (1989), this refers to a model in which the earnings surprise is defined as the difference between the current quarter's earnings and earnings one year earlier. Since we are using I/B/E/S estimates, it seems useful to change the terminology to reflect the different methods.

The methodology for calculating the SES follows, among others, Livnat and Mendenhall (2006) and Doyle, Lundholm, and Soliman (2006). Our measure diverges from those two papers in two respects. First, we use only estimates within 30 days of the announcement and those papers include estimates within 90 days of the announcement. The shorter window helps avoid including estimates based on outdated information. For our sample of DJIA firms, the 30-day window is sufficient to have at least one estimate for 442 earnings announcements. Second, we use the closing stock price on the announcement day instead of the stock price at the end of the earnings quarter. Since we are analyzing intraday data, it would be more appropriate to standardize the SES using the price from the announcement day.

We divide our earnings sample into good and bad news. If SES is positive (negative), the earnings information is considered as good (bad) news. We hypothesize that the market reacts positively (negatively) to good (bad) news. Which price is noisy in reacting to news and which price reflects the new information? We focus our analysis on the close-to-open return and the 9:30-9:31 return. Specifically, we determine whether the mean return is positive (negative) in reaction to good (bad) news. We also compute the frequency of positive (negative) returns following good (bad) news.

In Table V, we present descriptive statistics for good and bad news. Note that 207 and 73 announcements are designated as good and bad news, implying the number of positive SES is almost three times the number of negative SES. During our sample period, good news appears to be dominant. For 21 announcements, SES is zero, meaning no surprises. With respect to good news, the mean return during 16:00-9:30 is significantly positive at the 1 percent level, while the mean return during 9:30-9:31 is close to zero. Also, the number of positive returns is far greater than the number of negative returns, or approximately 69 percent of the good news observations show positive returns during 16:00-9:30. On the other hand, during 9:30-9:31, the

frequency of positive returns is the same as the frequency of negative returns. This evidence confirms that good news is fully reflected in the close-to-open return, and the price movement between 9:30 and 9:31 does not represent any further adjustment to good news on earnings.

In the case of bad news, we have similar results for the close-to-open return. The mean return is again significantly negative at the 1 percent level and the magnitude is even bigger compared to the case of good news. The frequency of negative returns is about 68 percent. For the 9:30-9:31 return, the mean return is still significantly negative at the 5 percent level, and the frequency of negative returns is 20 percent higher than the frequency of positive returns. Our analysis provides a possible asymmetric response of the market to good versus bad news. The impact of bad news seems greater and lasts longer as it continues into the first minute following the market open. This asymmetric reaction becomes more apparent when we compare the top 20 best surprises with the top 20 worst surprises. The mean close-to-open returns are 1.02 percent and -3.27 percent for good and bad news, respectively. The frequencies of positive and negative returns are 70 percent and 85 percent for good and bad news, respectively.

To summarize, good news on earnings is fully reflected in the opening price, and the 9:30-9:31 return seems to be driven by uninformed trading. Bad news on earnings also largely impacts the close-to-open return. And there is some *weak* evidence that the 9:30-9:31 return tends to represent a continuing adjustment to bad news.

B. Further Evidence on Market Efficiency and Information Leakage

In the previous section, we showed that the 9:30-9:31 return is independent of the close-to-open return, implying that the earnings news is fully reflected in the opening price. We determine whether this result is robust to the news content. Specifically, we compute correlations between the 16:00-9:30 return and one-minute returns during the first 5 minutes of trading with respect to good and bad news. Our results are summarized in Table VI.

For good news (n=207), the 9:30-9:31 and 9:31-9:32 returns are negatively correlated with the close-to-open return at the 10 and 1 percent levels, respectively. This implies that the equity market may overreact to good news at the market open, and some correction is made during the first two minutes of trading. The 9:31-9:32 and 9:32-9:33 returns also exhibit negative correlations with the 9:30-9:31 return, and again there may be overreaction during 9:30-9:31. In the case of bad news (n=73) and no surprises (n=21), one-minute returns during the first 5 minutes of trading are all independent of the close-to-open return, confirming the previous overall result that new information on earnings is fully reflected in the close-to-open return. The negative correlation between the 9:30-9:31 and 9:33-9:34 returns on the bad news days may imply a possible overreaction during 9:30-9:31. When we focus on the top 20 best news, there is no particularly interesting result. For the top 20 worst news, the 9:31-9:32 and 9:33-9:34 returns are negatively correlated with the 9:30-9:31 return at the 5 percent level, implying a possible overreaction to extremely bad news during the first minute of trading.

In regard to the information leakage issue, we previously reported positive correlations between the 15:58-15:59 return and the close-to-open return. Table VII presents further results for good and bad news. In the case of good news (n=207), the 15:57-15:58 return is positively correlated with the close-to-open return at the 5 percent level, and it is positively correlated with the 15:59-16:00 return at the 5 percent level as well. This evidence suggests a possible leakage of good news about three minutes prior to the market close. For bad news (n=73), the positive correlation between the 15:58-15:59 return and the close-to-open return implies a possible leakage about two minutes before the market close. The negative correlation of the 15:58-15:59 return and the positive correlation of the 15:57-15:58 return for the case of no surprises (n=21) do not seem quite meaningful. These results become much clearer when we consider the top 20 best and 20 worst news. The correlation between the 15:59-16:00 return and the close-to-open

return is significantly positive at the 1 percent level for the top 20 best news. Similarly, the 15:58-15:59 return is significantly positively correlated with the close-to-open return at the 1 percent level for the top 20 worst news.

C. Other Considerations

We consider three other aspects in conjunction with market efficiency and information leakage: (1) after-close announcements versus pre-open announcements, (2) good and bad news based on the close-to-open return, and (3) good and bad news based on both SES and the close-to-open return.

We define after-close announcements as the announcements made between the market close (16:00) and midnight, and pre-open announcements as the announcements made between midnight and the market open (9:30). As mentioned earlier, most after-close announcements are made during the first thirty minutes following the market close. Out of 109 announcements, 104 announcements were clustered during the 16:00-16:30 interval. Also, 375 announcements out of 381 pre-open announcements were made during the 6:00-9:00 interval. We sort our sample according to after-close announcements and pre-open announcements. We then hypothesize that after-close announcements exhibit evidence on information leakage more than pre-open announcements, since the time lag between the market close and the announcement is usually less than 30 minutes. On the other hand, we hypothesize that pre-open announcements lead to further price adjustments more than after-close announcements, given 0.5-3.5 hours between the announcement and the market open.

We conduct the leakage and efficiency analysis for after-close announcements and separately for pre-open announcements. As reported in Table VIII, there is no distinctive pattern in price movements following the pre-open announcements during 9:30-9:35, compared to the after-close announcements. Only the 9:32-9:33 return is positively correlated with the close-to-

open return at the 10 percent level. Regarding the information leakage, the 15:58-15:59 return is positively correlated with the close-to-open return at the 1 percent level for the entire sample. This correlation still remains positive at the 1 percent and 5 percent levels for the pre-open and after-close announcements, respectively. Even the 15:59-16:00 return shows positive correlation with the close-to-open return for the pre-open announcements. Again, the after-close announcements do not provide any particularly stronger evidence on information leakage.[17] Our hypothesis that after-close and pre-open announcements lead to different results is not supported.

The main advantage of the SES as a measure of good and bad news is that it provides a quantitative measure with earnings numbers. However, when earnings news is released, some qualitative information is also announced as part of earnings announcement. For example, before the market opened on October 17, 2005, GM announced earnings of -$1.92 per share. In the 30 days prior to the announcement, the mean earnings forecast reported by I/B/E/S was -$0.68 per share, where GM's SES for that announcement turns out the second worst news in our sample. When GM announced its earnings figure, it confirmed that an agreement was reached with its union to reduce health care costs for the workers. GM's stock price rose sharply, and the return on October 17, 2005 was 11.53%. The bad news about earnings was clearly dominated by the health care cost news. In this case, the GM earnings announcement must have been perceived as good news in the market.[18]

To account for the potential problem that earnings announcements can contain additional information along with earnings numbers, we attempt to sort the announcements into good and bad news based on the market response. We define good news as a positive close-to-

[17] One possible reason is that both the extremely good and extremely bad standardized earnings surprises are dominated by the pre-open announcements. For example, firms that announce before the market opens have 19 of the 20 largest standardized earnings surprises. If large surprises tend to leak, pre-open announcements would probably give evidence on information leakage as much as after-close announcements.

[18] In fact, out of 207 positive SES's, 142 observations had positive close-to-open returns. Similarly, 50 of 73 negative SES's had negative close-to-open returns.

open return around the announcement and bad news as a negative close-to-open return. Correlation coefficients are shown in Table IX. Consider the correlation between the close-to-open return and one-minute returns from 9:30 to 9:35. Consistent with our previous finding, there is no evidence in Table IX that the overnight price adjustment continues in to the first minute of trading. In the case of information leakage, we previously reported possible leakage of news about 1 to 3 minutes before the market close. In Table IX, the case of good news is similar to the previous finding. However, for bad news, we found significantly negative correlations between one-minute returns from 15:55 to 15:58 and the close-to-open return, implying possible leakage of false information.

Finally, we define good news as a positive SES with a positive close-to-open return, and bad news with a negative SES with a negative close-to-open return. As shown in Table X, the overall results for information leakage are similar to the case where good and bad news are based on the close-to-open return. There is a possible leakage of good news, while bad news seems to leak falsely. However, unlike the previous results, the 9:30-9:31 return for bad news is significantly positively correlated with the close-to-open return, implying that the overnight reaction to bad news continues to the first minute of trading.

V. Price Movement Patterns – AR and CAR

We now explore price movement patterns around the earnings announcement, i.e., from 15:55 to 9:35 the next day. As shown above, the SES can be used as a measure of good and bad news. We define adjusted returns, AR_t, for each one-minute interval and the overnight interval as

$$AR_t = R_t * D_t \tag{3}$$

where R_t is the log return for interval t and $D_t = 1$ if $SES > 0$, $D_t = -1$ if $SES < 0$, and

$D_t = 0$ if $SES = 0$. The average adjusted returns, AAR_t, are computed for announcement days and the corresponding control days. For example, for the entire sample of 301 announcements sorted into good, bad, and neutral earnings surprises, AAR_t, for interval t is the average of the 301 adjusted returns. If there is no information leakage before the market close, $AAR_t = 0$ from 15:55 to 16:00. If the price reacts to the earnings announcement during 16:00-9:30, $AAR_t > 0$ for the overnight interval. If there is further adjustment after the market open, $AAR_t > 0$ from 9:30 to 9:35, and $AAR_t = 0$ when the adjustment is complete. The cumulative average adjusted returns, $CAAR_t$, is measured as the sum of AAR_t from 15:55 to t.

The price movement patterns across the 301 earnings announcement days and the 615 corresponding control days are shown in Figure 4. The announcement day AARs and CAARs are reported in Table XI for each interval. The ratio of $CAAR_t$ to the CAAR from 15:55 to 9:35 is also reported to measure how much of the overall adjustment is completed by time t, assuming that the 9:35 price is the fully adjusted price.[19] The results in Figure 4 and Table XI confirm our earlier finding that the overnight return volatility on announcement days is far greater than on control days. The CAAR pattern on the control days is basically flat compared to the announcement days. The control day CAARs are close to zero until 16:00, and become slightly negative afterwards.

Contrary to the control days, there is a sharp increase in the announcement day CAARs during the overnight period. The AAR during 15:59-16:00 is positive at the 5 percent significance level. The overnight AAR is 1.21%, which is significant at the 1 percent level and

[19] Woodruff and Senchak (1988) use the closing price at the end of the trading day following the earnings announcement as the "fully-realized" price. They compare the price at various intervals – 30 minutes, 1 hour, 2 hours, etc. – to the fully realized price. When we follow their approach and the same criteria for most favorable and unfavorable earnings surprises, our results are quite different from theirs. The negative surprises show about an 80% adjustment at the open, and then it takes most of the day for the 80% to reach 100%. For the positive surprises, the adjustment at the open is about 120%, and then it takes most of the day to go down to 100%. The market responds much faster now than when Woodruff and Senchak wrote their paper, and there is some underreaction to bad news and overreaction to good news.

more than 80 times the 15:59-16:00 AAR. The 9:30-9:31 AAR is also significant at the 5 percent level. Although the 15:59-16:00 and 9:30-9:31 AARs are significant, they are completely dominated by the overnight AAR. In fact, the CAAR ratios are 1%, 92%, and 99% for the 15:59-16:00, 16:00-9:30, and 9:30-9:31 intervals, respectively. This evidence implies an ignorable information leakage one minute prior to the market close, most of price adjustment completed during the overnight period, and a little more adjustment for one more minute after the market open. It is very clear that the impact of earnings announcements on the market is almost complete at the market open, and at most one more minute to reach the new equilibrium price.[20]

To see if there is any difference in the market response to good news versus bad news, we divide the earnings announcement days into the good news and bad news announcement days based on the SES, where the announcement days with zero SES are excluded. The AARs, CAARs, and the ratios are reported in Table XI for the 207 good news days and the 73 bad news days, and the corresponding price movement patterns are also shown in Figure 5. The 16:00-9:30 AARs are significant for both good and bad news at the 1 percent level, reinforcing our previous finding that the overnight return largely reflects the impact of announcements. Interestingly, however, the AAR for bad news is almost twice the good news AAR during the overnight period, and this is exhibited in Figure 5 in terms of the CAARs. This evidence is consistent with our earlier results of a possible asymmetric response of the market to good versus bad news. We showed in Section IV.A that the impact of bad news seems much greater and lasts longer as it continues into the first minute following the market open.

In the case of good news, the price adjustment begins about two minutes prior to the market close and it almost ends at the market open. The good news AAR during 15:58-15:59 is

[20] Also, the evidence of a possible mild overreaction reported earlier in Table IV is not supported here as the 9:31-9:32 AAR is not significantly negative.

significant at the 5 percent level. The CAAR ratio is 1%, 2%, and 95% for the 15:58-15:59, 15:59-16:00, and 16:00-9:30 intervals, respectively. Even though the 9:30-9:31 AAR is not significant, it is still positive and its CAAR ratio is 103%. So the price adjustment seems to be completed at 9:31. On the bad news days, the price adjustment continues into the next minute after the market open, while there seems no information leakage with insignificant AARs prior to the market close. As shown in Table XI and Figure 5, the CAAR ratio is 0%, 87%, and 93% for the 15:59-16:00, 16:00-9:30, and 9:30-9:31 intervals, respectively. Again, the 9:31-9:32 AAR is still positive and the CAAR ratio is 102%, implying that the price adjustment to bad news is completed at 9:32. The market appears to react to good news a little faster, but the magnitude of the price adjustment is much bigger for bad news. The impact of bad news also lasts longer as well.

The evidence of a possible overreaction during 9:30-9:31 to good and bad news raised earlier from the results in Table VI is weakly supported here. In Table VI, the 9:31-9:32 and 9:32-9:33 returns are significantly negatively correlated with the 9:30-9:31 return for good news, and the 9:33-9:34 return is significantly negatively correlated with the 9:30-9:31 return for bad news. In Table XI, both the 9:31-9:32 and 9:32-9:33 AARs on the good news days are negative, although they are statistically significant. On the bad news days, the 9:33-9:34 AAR is significantly negative at the 10 percent level, which is consistent with the result in Table VI. Figure 5 shows some overreaction during 9:31-9:32 and the following correction during 9:32-9:33 and 9:33-9:34 on the bad news days.

VI. Conclusions

This paper has examined how new information transmits to equity markets, using quarterly earnings announcements and intraday price data for the DJIA stocks. Our most

important findings are as follows.

First, over the 11-day window that includes the announcement day, we find the abnormally high volatility concentrated on the announcement day, no volatility spillover into the subsequent days, and no volatility increase on the days prior to earnings announcements. On an intraday basis, we observe a matchless volatility spike from the market close on the day before announcements to the market open, implying that the market is completely awake in responding to the new information on earnings. The opening price fully reflects the earnings news. Also, volatility is substantially higher than normal for the first five minutes of trading, sharply decreases for the next five minutes, and it still remains relatively high for about two hours in the morning.

Second, the speed of information transmission is scrutinized, using minute-by-minute returns. Within the first five minutes following the overnight major adjustment, the further impact of announcements is observed for the first two minutes, and the volatility response is almost complete at the end of four minutes. As one-minute returns from 9:30 to 9:34 are independent of the 16:00-9:30 overnight return, the market turns out efficient in the sense that no profits can be earned by a trader with immediate market access. The continued high volatility during 9:30-9:34 may be due to noise traders who react slowly to earnings announcements. We also find mild evidence that information leaks about two minutes prior to the market close.

Finally, we use the standardized earnings surprise (SES) as a measure of good and bad news, and find that good (bad) news leads to a positive (negative) overnight return and that the 9:30-9:31 return is independent of news content. This confirms that the overnight return truly reflects new information on earnings and that the uncorrelated 9:30-9:31 return is noisy. This is the case particularly for good news, and the impact of bad news is greater than good news and continues into the first minute of trading. Price movement patterns from 15:55 to 9:35 on the

basis of AAR and CAAR indicate again a negligible information leakage during the last minute before the market close, nearly all price adjustment over the night, and a very small adjustment for one minute after the market open. The CAAR patterns for good and bad news reinforces the earlier finding on the asymmetric response of stock prices to bad news.

While we do not address the issue of PEAD directly, our overall results make PEAD even more of an anomaly as it seems the market is becoming better and faster at processing information, but numerous papers still report that PEAD persists. If the market can process most of the information in earnings announcements in the opening price, why would earnings drift over weeks or months exist?

Appendix: DJIA Component Stocks during 2002-2006[a]

1. 3M Company	10. Exxon Mobil	19. J.P. Morgan Chase
2. Alcoa Inc	11. General Electric	20. McDonald's
3. Altria Group	12. General Motors	21. Merck
4. American Express	13. Hewlett-Packard	22. Microsoft
5. Boeing Company	14. Home Depot	23. Procter & Gamble
6. Caterpillar	15. Honeywell	24. United Technologies
7. Citigroup	16. Intel	25. Wal-Mart
8. Coca-Cola	17. IBM	26. Walt Disney
9. DuPont	18. Johnson & Johnson	

[a] AT&T, Eastman Kodak, and International Paper in the DJIA were replaced by AIG, Pfizer, and Verizon on 4/8/04. Also, SBC Communications merged with AT&T on 11/21/05 and changed its name to AT&T Incorporated. So we exclude AT&T, Eastman Kodak, International Paper, and SBC from the sample, which leaves 26 firms in the DJIA for the period from 2002 through 2006.

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Table I

Difference of Daily Return Volatilities between Announcement and Control Periods

Daily return standard deviations are reported and compared for announcement and control periods. The reported standard deviations are 10^3 times the calculated values. Announcement periods cover from D-5 through D+5, where D0 is the close-to-close interval that encompasses the overnight earnings announcement. For control periods, D-5±4 weeks through D+5±4 weeks correspond to D-5 through D+5. The ratio of the announcement period standard deviation to the control period standard deviation is shown, and the Brown-Forsythe-modified Levene test statistic for homoskedasticity between the announcement and the control periods is reported. One, two, and three asterisks denote significance at 2, 0.5, and 0.01 percent levels, respectively. The data period is from 01/02/2002 through 12/31/2006.

	D-5	D-4	D-3	D-2	D-1	D0	D+1	D+2	D+3	D+4	D+5
Announce	17.91	17.79	17.19	16.70	17.93	39.65	18.24	16.69	20.17	19.89	17.96
Control	16.37	17.67	15.91	17.53	16.85	15.51	16.49	15.32	15.57	15.72	18.62
σ ratio	1.09	1.01	1.08	0.95	1.06	2.56	1.11	1.09	1.30	1.27	0.96
B-F-L F stat	2.22	0.17	2.03	0.27	3.94	300.35***	4.96	4.09	6.26*	2.82	0.10

Table II

Volatility Persistence Following Earnings Announcements

Five-minute return standard deviations following overnight earnings announcements are reported and compared with control periods. The reported standard deviations are 10^3 times the calculated values. All five-minute return standard deviations from 9:30 to 10:30 are reported, and at thirty-minute intervals thereafter, including the last five-minute interval of the day. The ratio of the announcement period standard deviation to the control period standard deviation is shown, and the Brown-Forsythe-modified Levene test statistic for homoskedasticity between the announcement and the control periods is reported. Two and three asterisks denote significance at the 0.5 and 0.01 percent levels, respectively. The data period is from 01/02/2002 through 12/31/2006.

	9:30-9:35	9:35-9:40	9:40-9:45	9:45-9:50	9:50-9:55	9:55-10:00	10:00-10:05	10:05-10:10	10:10-10:15	10:15-10:20	10:20-10:25	10:25-10:30
Announce	16.98	8.40	6.89	4.15	4.22	3.76	3.47	3.29	3.13	3.14	3.02	2.98
Control	7.02	3.51	2.69	2.39	2.39	2.18	2.48	2.31	2.10	2.02	1.92	1.83
σ ratio	2.42	2.39	2.56	1.73	1.76	1.72	1.40	1.43	1.49	1.56	1.57	1.63
B-F-L F	121.01***	100.77***	74.47***	131.77***	108.42***	113.14***	57.46***	47.47***	71.47***	73.62***	64.76***	65.62***
	10:30-10:35	11:00-11:05	11:30-11:35	12:00-12:05	12:30-12:35	13:00-13:05	13:30-13:35	14:00-14:05	14:30-14:35	15:00-15:05	15:30-15:35	15:55-16:00
Announce	2.54	2.34	1.88	1.83	1.69	1.68	1.54	1.53	1.80	1.65	1.79	2.26
Control	1.99	1.73	1.60	1.46	1.21	1.23	1.21	1.30	1.51	1.44	1.72	1.86
σ ratio	1.27	1.35	1.18	1.25	1.40	1.36	1.27	1.17	1.19	1.15	1.04	1.21
B-F-L F	21.97***	48.32***	15.25**	13.85**	26.78***	27.40***	17.93***	13.46**	11.99**	7.59**	5.08	21.02***

Table III

The Speed of the Information Transmission to Equity Markets: Minute-by-Minute Reaction to Earnings Announcements

Results of the regression $|R_{jt} - \overline{R}_j| = a_{0j} + a_{1j} D_t + e_{jt}$ are reported. R_{jt} is the log return over the one-minute interval j, and $D_t = 1$ if the earnings announcement is released prior to the market open. The regression is estimated for j intervals of 9:30-9:31 through 9:59-10:00 over all announcement and control days for the DJIA index stocks during the period from 01/02/2002 to 12/31/2006. For 162 announcement days, there are no trades recorded in the TAQ database during the 9:30:00 to 9:31:00 interval so those days are excluded from the sample. As a result, the sample size is reduced from 490 to 328 earnings-announcement days. For the control days, there are 261 days with no trades recorded during the 9:30:00 to 9:31:00 interval so the sample size is reduced from 980 to 719 control days. The reported coefficients are the actual coefficients times 10^3. One, two, and three asterisks denote significance at the 2, 0.5, and .01 percent levels, respectively

Time	9:30-9:31	9:31-9:32	9:32-9:33	9:33-9:34	9:34-9:35	9:35-9:36	9:36-9:37	9:37-9;38	9:38-9:39	9:39-9:40
a_0	1.13***	1.40***	1.16***	1.04***	1.03***	1.01***	1.01***	0.90***	0.93***	0.86***
a_1	1.70***	1.60***	0.78***	1.22***	0.63***	0.73***	0.66***	0.68***	0.57***	0.42***
Time	9:40-9:41	9:41-9:42	9:42-9:43	9:43-9:44	9:44-9:45	9:45-9:46	9:46-9:47	9:47-9;48	9:48-9:49	9:49-9:50
a_0	0.91***	0.89***	0.77***	0.84***	0.83***	0.77***	0.76***	0.79***	0.78***	0.81***
a_1	0.44***	0.45***	0.50***	0.51***	0.49***	0.53***	0.45***	0.36***	0.33***	0.45***
Time	9:50-9:51	9:51-9:52	9:52-9:53	9:53-9:54	9:54-9:55	9:55-9:56	9:56-9:57	9:57-9;58	9:58-9:59	9:59-10:00
a_0	0.79***	0.72***	0.76***	0.69***	0.75***	0.71***	0.67***	0.69***	0.68***	0.63***
a_1	0.41***	0.43***	0.30***	0.30***	0.31***	0.27***	0.35***	0.39***	0.35***	0.39***

Table IV

Correlation Matrices

Pearson correlation coefficients between the previous close-to-open return and one-minute returns for the first five minutes of trading on the announcement day and for the last five minutes of trading on the day prior to the announcement are reported in Panel A and Panel B, respectively. Observations with no trading at the open are excluded from the sample. One, two, and three asterisks denote significance at the 10, 5, and 1 percent levels, respectively. The data period is from 01/02/2002 through 12/31/2006.

Panel A: Close-to-open vs.9:30-9:35 (n=301)			Panel B: 15:55-16:00 vs. close- to-open (n=301)		
	16:00-9:30	9:30-9:31		16:00-9:30	15:59-16:00
16:00-9:30	1.00		15:55-15:56	-0.09	0.05
9:30-9:31	0.00	1.00	15:56-15:57	-0.07	0.02
9:31-9:32	-0.05	-0.11**	15:57-15:58	0.00	0.15***
9:32-9:33	0.05	-0.05	15:58-15:59	0.18***	-0.04
9:33-9:34	-0.01	0.06	15:59-16:00	0.04	1.00
9:34-9:35	-0.00	0.01	16:00-9:30	1.00	

Table V

Descriptive Statistics for Good News and Bad News

We divide the data into good and bad earnings news. Good news and bad news are defined as standardized earnings surprises that are greater than zero and less than zero, respectively. No surprise means zero standardized earnings surprise. Top 20 refers to the 20 best and 20 worst standardized earnings surprises. Observations with no trading at the open are excluded from the sample. For the 9:30 to 9:31 returns, some returns equal zero. One, two, and three asterisks denote significance at the 10, 5, and 1 percent levels, respectively. The data period is from 01/02/2002 through 12/31/2006.

	All (n=301)	Good news (n=207)	Bad news (n=73)	No surprise (n=21)	Top 20 good (n=20)	Top 20 bad (n=20)
	Close-to-open					
Mean return (%)	0.24	1.03***	-2.06***	0.43	1.02*	-3.27**
No. of + returns	176	142	22	12	14	3
No. of - returns	122	63	50	9	5	17
No. of 0 returns	3	2	1	0	1	0
	9:30-9:31					
Mean return (%)	0.02	0.09	-0.15**	-0.02	-0.01	-0.24
No. of + returns	106	76	25	5	8	6
No. of - returns	111	76	30	5	9	9
No. of 0 returns	84	55	18	11	3	5

Table VI

Market Efficiency with Respect to Good and Bad News

We divide the data into good and bad earnings news. Good news and bad news are defined as standardized earnings surprises that are greater than zero and less than zero, respectively. No surprise means zero standardized earnings surprise. Top 20 refers to the 20 best and 20 worst standardized earnings surprises. Observations with no trading at the open are excluded from the sample. For the 9:30 to 9:31 returns, some returns equal zero. The correlations between the 16:00-9:30 return and one-minute returns from 9:30 to 9:35 are reported. Similarly, the correlations between the 9:30-9:31 return and the successive one-minute returns are also reported. One, two, and three asterisks denote significance at the 10, 5, and 1 percent levels, respectively. The data period is from 01/02/2002 through 12/31/2006.

	Good news (n=207)		Bad news (n=73)		No surprise (n=21)		Top 20 good (n=20)		Top 20 bad (n=20)	
	16:00-9:30	9:30-9:31	16:00-9:30	9:30-9:31	16:00-9:30	9:30-9:31	16:00-9:30	9:30-9:31	16:00-9:30	9:30-9:31
16:00-9:30	1.00		1.00		1.00		1.00		1.00	
9:30-9:31	-0.12*	1.00	0.09	1.00	0.10	1.00	-0.03	1.00	0.30	1.00
9:31-9:32	-0.19***	-0.17**	-0.04	-0.11	-0.24	-0.19	-0.36	0.10	-0.01	-0.44**
9:32-9:33	0.11*	-0.11*	0.01	0.13	-0.19	-0.15	0.33	-0.18	0.22	0.30
9:33-9:34	0.07	0.10	-0.18	-0.29**	0.12	0.19	0.02	0.08	-0.08	-0.50**
9:34-9:35	-0.09	0.01	0.07	-0.04	0.10	0.30	-0.09	0.03	0.04	0.10

Table VII

Information Leakage with Respect to Good and Bad News

We divide the data into good and bad earnings news. Good news and bad news are defined as standardized earnings surprises that are greater than zero and less than zero, respectively. No surprise means zero standardized earnings surprise. Top 20 refers to the 20 best and 20 worst standardized earnings surprises. Observations with no trading at the open are excluded from the sample. For the 9:30 to 9:31 returns, some returns equal zero. The correlations between the 16:00-9:30 return and one-minute returns from 15:55 to 16:00 are reported. Similarly, the correlations between the 15:59-16:00 return and the previous one-minute returns are also reported. One, two, and three asterisks denote significance at the 10, 5, and 1 percent levels, respectively. The data period is from 01/02/2002 through 12/31/2006.

	Good news (n=207)		Bad news (n=73)		No surprise (n=21)		Top 20 good (n=20)		Top 20 bad (n=20)	
	16:00-9:30	15:59-16:00	16:00-9:30	15:59-16:00	16:00-9:30	15:59-16:00	16:00-9:30	15:59-16:00	16:00-9:30	15:59-16:00
15:55-15:56	0.05	0.04	-0.18	0.07	0.06	0.02	0.34	-0.03	-0.06	0.26
15:56-15:57	0.04	0.00	-0.21*	0.20*	0.18	-0.33	-0.15	-0.01	0.04	0.04
15:57-15:58	0.14**	0.14**	-0.20*	0.16	0.52**	0.14	0.09	-0.01	-0.12	0.03
15:58-15:59	0.06	-0.06	0.46***	-0.04	-0.47**	0.08	-0.14	0.10	0.65***	0.18
15:59-16:00	-0.05	1.00	0.09	1.00	0.04	1.00	0.57***	1.00	0.35	1.00
16:00-9:30	1.00		1.00		1.00		1.00		1.00	

Table VIII

After-Close Announcements and Pre-Open Announcements

We sort the data according to after-close announcements and pre-open announcements. We define after-close announcements as the announcements made between the market close (16:00) and midnight, and pre-open announcements as the announcements made between midnight and the market open (9:30). Of the 490 observations in the sample, 162 have no trading at the open and are excluded from the sample for a total of 328 observations. The correlations between the 16:00-9:30 return and one-minute returns from 9:30 to 9:35 and between the 16:00-9:30 return and one-minute returns from 15:55 to 16:00 are reported. One, two, and three asterisks denote significance at the 10, 5, and 1 percent levels, respectively. The data period is from 01/02/2002 through 12/31/2006.

	All (n=328)	Pre-open (n=235)	After-close (n=93)		All (n=328)	Pre-open (n=235)	After-close (n=93)
	16:00-9:30	16:00-9:30	16:00-9:30		16:00-9:30	16:00-9:30	16:00-9:30
16:00-9:30	1.00	1.00	1.00	15:55-15:56	-0.09	0.00	-0.19*
9:30-9:31	0.00	-0.02	0.05	15:56-15:57	-0.07	-0.05	-0.10
9:31-9:32	-0.05	0.00	-0.07	15:57-15:58	0.00	0.07	-0.07
9:32-9:33	0.05	0.11*	-0.05	15:58-15:59	0.18***	0.17***	0.21**
9:33-9:34	-0.01	-0.03	0.01	15:59-16:00	0.04	0.16**	-0.08
9:34-9:35	0.00	-0.02	0.02	16:00-9:30	1.00	1.00	1.00

Table IX

Good and Bad News Based on the Close-to-Open Return

We divide the data into good and bad earnings news. Good news and bad news are defined as positive and negative close-to-open returns, respectively. Three firms had close-to-open returns equal to zero. Observations with no trading at the open are excluded from the sample. For the 9:30 to 9:31 returns, some returns equal zero. Top 20 refers to the 20 best and 20 worst close-to-open returns. The correlations between the 16:00-9:30 return and one-minute returns from 9:30 to 9:35 and between the 16:00-9:30 return and one-minute returns from 15:55 to 16:00 are reported. One, two, and three asterisks denote significance at the 10, 5, and 1 percent levels, respectively. The data period is from 01/02/2002 through 12/31/2006.

	Good news (n=176)	Bad news (n=122)	Top 20 good (n=20)	Top 20 bad (n=20)		Good news (n=176)	Bad news (n=122)	Top 20 good (n=20)	Top 20 bad (N=20)
	16:00-9:30	16:00-9:30	16:00-9:30	16:00-9:30		16:00-9:30	16:00-9:30	16:00-9:30	16:00-9:30
16:00-9:30	1.00	1.00	1.00	1.00	15:55-15:56	0.07	-0.23**	0.00	-0.45**
9:30-9:31	-0.10	0.06	-0.26	0.21	15:56-15:57	0.05	-0.16*	0.39*	-0.46**
9:31-9:32	-0.05	-0.15*	0.23	-0.17	15:57-15:58	0.25***	-0.32***	0.23	-0.50**
9:32-9:33	0.02	-0.03	-0.13	-0.12	15:58-15:59	0.22***	0.15	0.51**	0.38*
9:33-9:34	-0.03	-0.06	0.05	-0.35	15:59-16:00	0.00	0.06	-0.18	-0.07
9:34-9:35	-0.13*	0.09	-0.21	0.26	16:00-9:30	1.00	1.00	1.00	1.00

Table X

Good and Bad News Based on the Standardized Earnings Surprise and the Close-to-Open Return

We divide the data into good and bad earnings news. We define good news as a positive standardized earnings surprise (SES) with a positive close-to-open return, and bad news as a negative SES with a negative close-to-open return. Three firms had close-to-open returns equal to zero. Observations with no trading at the open are excluded from the sample. Observations with either zero SES or zero close-to-open return are excluded from the sample. For the 9:30 to 9:31 returns, some returns equal zero. Top 20 refers to the 20 best and 20 worst standardized earnings surprises. The correlations between the 16:00-9:30 return and one-minute returns from 9:30 to 9:35 and between the 16:00-9:30 return and one-minute returns from 15:55 to 16:00 are reported. One, two, and three asterisks denote significance at the 10, 5, and 1 percent levels, respectively. The data period is from 01/02/2002 through 12/31/2006.

	Good news (n=142)	Bad news (n=50)	Top 20 good (n=20)	Top 20 bad (n=20)		Good news (n=142)	Bad news (n=50)	Top 20 good (n=20)	Top 20 bad (n=20)
	16:00-9:30	16:00-9:30	16:00-9:30	16:00-9:30		16:00-9:30	16:00-9:30	16:00-9:30	16:00-9:30
16:00-9:30	1.00	1.00	1.00	1.00	15:55-15:56	0.04	-0.31**	-0.10	-0.18
9:30-9:31	-0.08	0.30**	-0.13	0.54**	15:56-15:57	-0.01	-0.30**	-0.22	-0.17
9:31-9:32	-0.11	-0.14	-0.33	-0.40*	15:57-15:58	0.22***	-0.35**	0.05	-0.01
9:32-9:33	0.02	-0.12	0.26	-0.18	15:58-15:59	0.01	0.23	0.13	-0.12
9:33-9:34	-0.04	-0.18	0.23	-0.08	15:59-16:00	-0.07	0.18	0.12	0.31
9:34-9:35	-0.13	0.00	0.03	0.32	16:00-9:30	1.00	1.00	1.00	1.00

Table XI

The Magnitude of the Price Movement around the Earnings Announcements

Average adjusted returns (AAR) and cumulative average adjusted returns (CAAR) are reported. Adjusted returns, AR_t, for each one-minute interval and the overnight interval are defined as $AR_t = R_t * D_t$ where R_t is the log return for interval t and $D_t = 1$ if $SES > 0$ (good news), $D_t = -1$ if $SES < 0$ (bad news), and $D_t = 0$ if $SES = 0$ (neutral). AAR is the average of adjusted returns and CAAR is the sum of AAR from 15:55 to the given interval. The ratio of CAAR to the CAAR from 15:55 to 9:35 is reported. AAR and CAAR are the actual returns times 10^5. Observations with no trading at the open are excluded from the sample. For the 9:30 to 9:31 returns, some returns equal zero. One, two, and three asterisks denote significance at the 10, 5, and 1 percent levels, respectively. The data period is from 01/02/2002 through 12/31/2006.

	Earnings announcement days (n=301)			Good news days (n=207)			Bad news days (n=73)		
	AAR	CAAR	Ratio	AAR	CAAR	Ratio	AAR	CAAR	Ratio
15:55-15:56	-6.75	-6.75	-0.01	-5.03	-5.03	0.00	-13.58	-13.58	-0.01
15:56-15:57	-4.52	-11.28	-0.01	-3.36	-8.38	-0.01	-9.13	-22.71	-0.01
15:57-15:58	6.39	-4.88	0.00	4.45	-3.93	0.00	13.73	-8.98	0.00
15:58-15:59	8.57	3.69	0.00	15.80**	11.87	0.01	-9.45	-18.43	-0.01
15:59-16:00	14.85**	18.54	0.01	13.68	25.55	0.02	22.43*	4.00	0.00
16:00-9:30	1208.32***	1226.86	0.92	1031.08***	1056.63	0.95	2058.50***	2062.50	0.87
9:30-9:31	98.20**	1325.06	0.99	89.12	1145.75	1.03	152.19*	2214.69	0.93
9:31-9:32	41.00	1366.06	1.02	-11.33	1134.41	1.02	201.21	2415.90	1.02
9:32-9:33	-16.76	1349.30	1.01	-7.09	1127.32	1.01	-48.98	2366.92	1.00
9:33-9:34	-1.24	1348.06	1.01	15.07	1142.39	1.03	-47.86*	2319.06	0.98
9:34-9:35	-7.70	1340.36	1.00	-29.08*	1113.31	1.00	50.72	2369.78	1.00

Figure 1. Daily return volatilities around earnings announcements and during control periods. Standard deviations of daily (close-to-close) returns are reported around each overnight earnings announcement of the DJIA underlying stocks (*solid bars*) and during control periods (*open bars*). During announcement periods, "0" denotes the daily interval encompassing an overnight announcement. As the announcement is released after the market close or before the market open, "0" covers from the previous day's close to today's close. "+N" and "-N" are the intervals N days after and before "0", respectively. Control periods are 4 weeks before and after each announcement, where ["0"±4 weeks], ["+N"±4 weeks], and ["-N"±4 weeks] substitute for 0, +N, and –N, respectively. Daily observations from January 2, 2002 through December 31, 2006 are utilized for the quarterly earnings announcements of the DJIA underlying stocks.

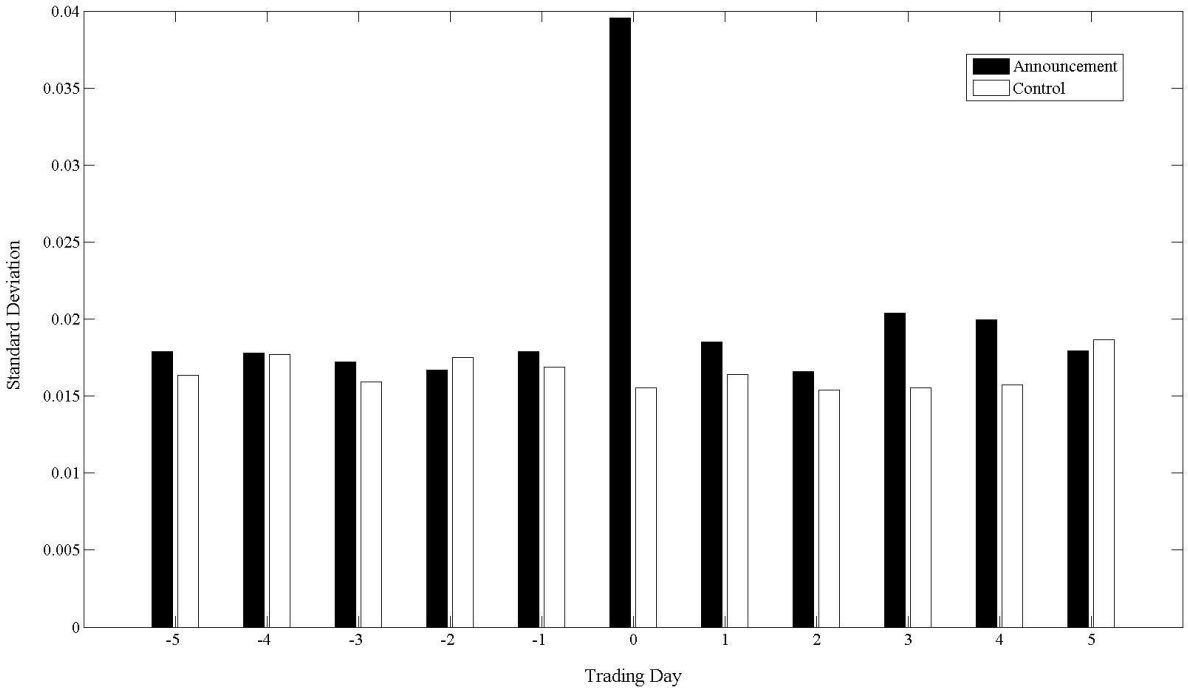

Figure 2. Close-to-open and five-minute intraday returns. The price of the last trade for any given interval is used as the price at the ending point in time, e.g., if the last trade occurs at 9:39:57 for the 9:35-9:40 interval, then the 9:39:57 price is sampled as the 9:40:00 price. However, since the first trade of the day may occur after 9:30:00, the first trade at or after 9:30:00 is sampled as the 9:30:00 price.

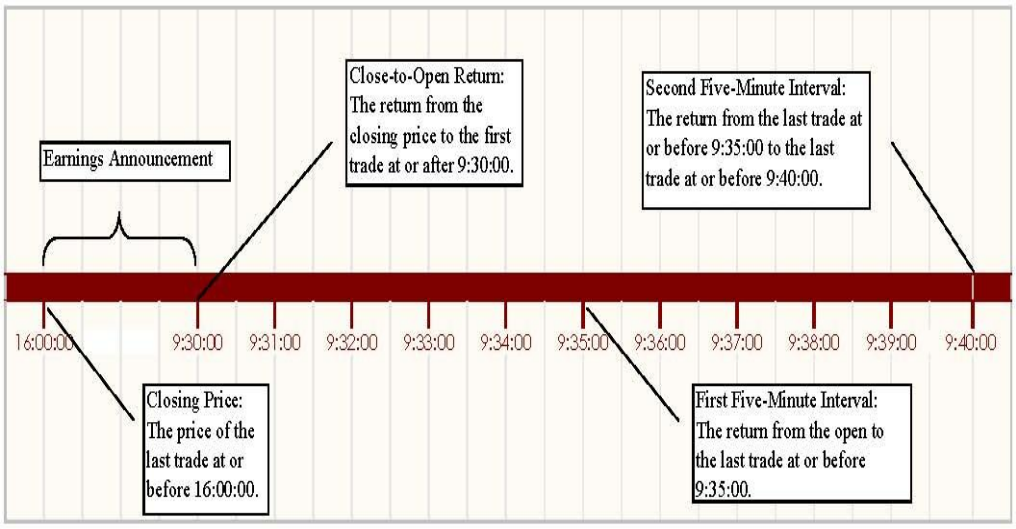

Figure 3. Intraday return volatilities following overnight earnings announcements and during control periods. Standard deviations of five-minute returns are reported from the day before each overnight earnings announcement of the DJIA underlying stocks (*solid line*) to the day following the announcement, and during the corresponding control period (*dashed line*). The times shown are five-minute interval ending times in Eastern Time, e.g., 10:00 for the 9:55-10:00 interval with an exception of 9:30 for the previous close-to-open interval. The control period is 4 weeks before and after each announcement. Five-minute interval observations from January 2, 2002 through December 31, 2006 are utilized for the quarterly earnings announcements of the DJIA underlying stocks.

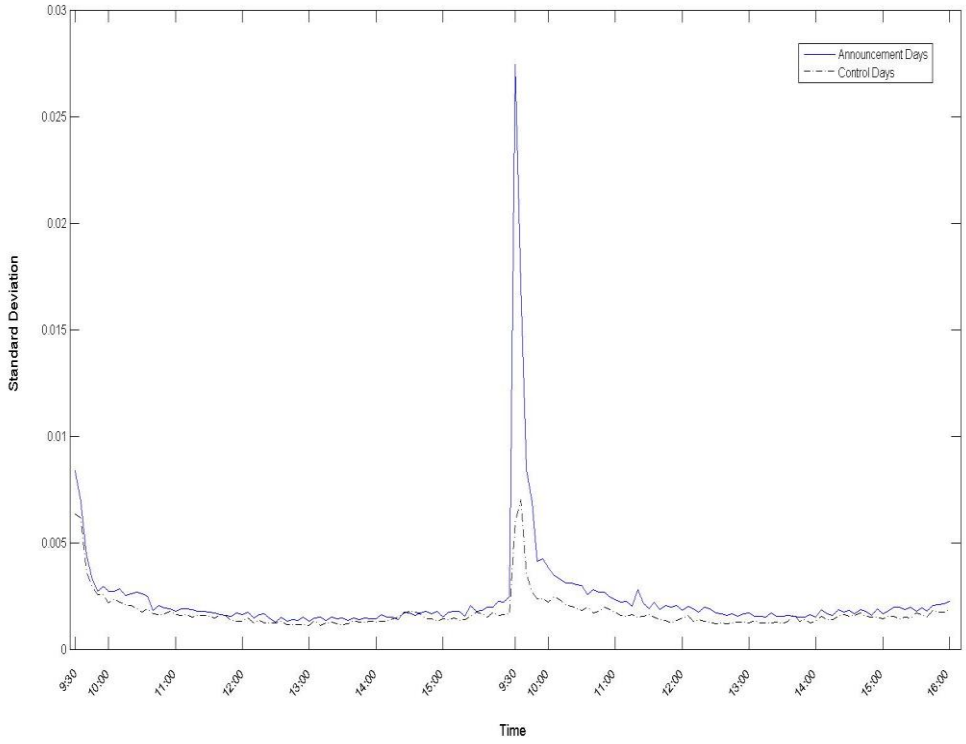

Figure 4. The Price Movement Patterns on Earnings Announcement Days and Control Days. Cumulative average adjusted returns (CAAR) are reported for earnings announcement days (*solid line*) and the corresponding control days (*dashed line*). CAAR is the sum of the average adjusted returns (AAR) from 15:55 to the time shown. Adjusted returns, AR_t, for each one-minute interval and the overnight interval are defined as $AR_t = R_t * D_t$ where R_t is the log return for interval t and $D_t = 1$ if $SES > 0$ (good news), $D_t = -1$ if $SES < 0$ (bad news), and $D_t = 0$ if $SES = 0$ (neutral). The reported AAR and CAAR are 10^5 times the calculated returns.

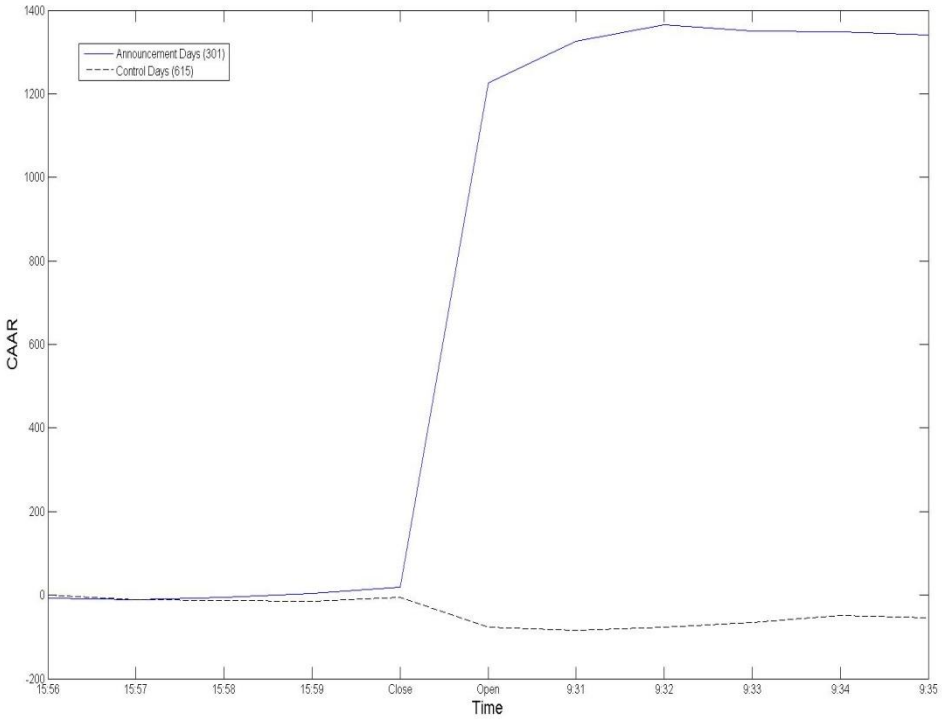

Figure 5. The Price Movement Patterns on Good News and Bad News Announcement Days. Cumulative average adjusted returns (CAAR) are reported for good news announcement days (*solid line*) and bad news announcement days (*dashed line*). CAAR is the sum of the average adjusted returns (AAR) from 15:55 to the time shown. Adjusted returns, AR_t, for each one-minute interval and the overnight interval are defined as $AR_t = R_t * D_t$ where R_t is the log return for interval t and $D_t = 1$ if $SES > 0$ (good news), $D_t = -1$ if $SES < 0$ (bad news), and $D_t = 0$ if $SES = 0$ (neutral). The reported AAR and CAAR are 10^5 times the calculated returns.