Trading Aggressiveness and its Implications for Market Efficiency*

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Abstract

This paper investigates the empirical relation between an increase in trading aggressiveness after earnings announcements and the speed of price adjustment. An increase in trading aggressiveness allows for quicker price changes within a given time interval that can be beneficial if the majority of aggressive orders are informative and push the price in the direction of its new equilibrium level. However, abnormal trading aggressiveness can also slow down the adjustment process if aggressive orders are mostly used by uninformed investors to trade on their heterogeneous beliefs. In this case, quick price changes in different directions might increase intraday volatility and the probability of price overshooting. Empirical findings of this paper suggest that the latter negative effect dominates, and it is especially harmful for illiquid stocks. Adjustment times of these stocks have increased compared to the time period before aggressive orders became available.

JEL classifications: G14, G18, G19

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1 Introduction

This paper analyzes the influence of abnormal trading aggressiveness on the speed of price adjustment after earnings announcement releases. An investor is trading aggressively if he prefers quicker execution of his limit order over a better execution price. Such a situation is most likely to arise when investors expect immediate changes in the value of a stock, and therefore the speed of order execution is of primary importance. Two recent examples of abnormal trading aggressiveness on the market are the Flash Crash (May 6, 2010), when the Dow Jones Industrial Average index (DJIA) dropped by more than 1,000 points in less than one hour, and the release of erroneous information about the United Airlines bankruptcy from Bloomberg on September 8, 2008. In both of these events, traders switched to the most aggressive orders on the market as soon as they realized that they were better off to have their orders executed immediately, even at inferior prices.[1] Waiting for execution at the best quoted price in such moments is costly, because the best quote might change by a large amount within the next second.

Quick action also pays off in periods immediately following corporate information releases. New information makes investors revise their beliefs, which leads to a subsequent increase in trading aggressiveness. What implications does abnormal trading aggressiveness have on the speed of price adjustment after a corporate information release? A higher execution speed of an aggressive order ensures that a larger portion of this order, as compared to a standard limit order, is executed within a given time interval. Thus, aggressive trading enables quicker price changes over relatively short time intervals. Quicker changes are beneficial if aggressive trading is informative and, thus, pushes the stock price more quickly towards its new equilibrium value. In contrast, if aggressive trades are mostly submitted by uninformed traders, who are just as likely to buy or to sell, then quick price changes in different directions might increase intraday volatility and the probability of price overshooting. An abnormal increase in intraday volatility makes the stabilization of a price at its new equilibrium value harder and slows down the adjustment process.[2] Empirical results of this paper show that, on average, the negative effect of increased trading aggressiveness dominates. Abnormal trading aggressiveness is especially harmful for stocks with low liquidity levels, because

[1] As documented by Chakravarty et al (2011b) for the Flash Crash day and Lei and Li (2010) for the false announcement of the United Airlines bankruptcy.

[2] Fleming and Remolona (1999) analyze a two-stage adjustment process in the U.S. Treasury market upon arrival of macroeconomic announcement releases. They identify the first stage as an almost immediate price reaction with a reduction in trading volume. The second "stabilization" stage lasts for more than an hour with abnormal price volatility, trading volume, and bid-ask spreads.

the adjustment times of illiquid stocks with abnormal trading aggressiveness are significantly longer compared to the time period before aggressive orders became available. However, the negative effect declines if aggressive trades are more informative and move the stock prices in the correct direction.

I measure trading aggressiveness as a proportion of the total volume that is executed through aggressive orders within a particular interval of time. To differentiate aggressive orders from non-aggressive ones, I use a new order type, called an intermarket sweep order (ISO), that represents the most aggressive trading instrument on U.S. equity markets. If an order is marked as an ISO, a trading venue has to give this order an immediate execution - even if this execution leads to a trade-through of the best quoted price.[3] Since an ISO is marked as such at the time of its submission, I can *ex post* observe investor preferences for the speed of order execution.

Earnings announcements are the most natural choice for this study, because they represent the most common type of information release for any stock. Further, earnings announcements are released regularly for a broad cross-section of firms in the market in the short period of time since ISOs became available in October 2007.

The major findings of this paper are as follows. First, I show that ISO trades have higher intraday price impacts than non-ISO trades and the difference in the price impacts between ISO and non-ISO trades is larger for illiquid stocks. The reason is that illiquid stocks have a thin order book with a lower number of shares quoted at each price, and, therefore, aggressive orders can move the prices of these stocks more easily. Further, I investigate the intraday changes in trading aggressiveness on earnings announcement days and document a significant 15% increase in the proportion of ISO volume in the first 15 minutes after an announcement release. Afterward, the proportion of the volume traded with aggressive orders steadily decreases, but it continues to deviate significantly from its base level until the end of the trading day. Additional analysis shows that the post-announcement jump in trading aggressiveness can be explained by a significant increase in the proportion of the sell volume of ISOs after the negative earnings surprises. This result suggests that investors trade more aggressively when confronted with negative news. For positive news releases, ISOs are largely uninformative in the first two hours after announcement releases with large increases in the proportions of ISO volume in both trading directions.

Further, this paper establishes the link between increases in investors' trading ag-

[3]Chakravarty et al (2010) provides an excellent overview of ISO characteristics and their use on the current financial markets.

gressiveness and the speed of price adjustment after earnings announcement releases.[4] The length of the price adjustment period is defined as the number of five-minute intervals from an announcement release until the interval in which the realized volatility of the one-minute midpoint returns is no longer abnormal.[5] For identification, I use a difference-in-differences approach that controls for differences in the speed of price adjustment of the stocks in the pre-Regulation National Market System (Reg NMS) period, when aggressive orders were not yet available. For this purpose, I require that each stock in my final sample has at least one announcement in each of the regulation subperiods.

The results of the difference-in-differences analysis suggest that the relation between the changes in trading aggressiveness and the speed of price adjustment is rather weak for liquid stocks, but exhibits a pronounced U-shape for stocks with low liquidity levels. Since liquid stocks have a deep limit order book, the adverse effects from increases in trading aggressiveness do not have a significant impact on the adjustment process of these stocks. By contrast, high increases in aggressive trading significantly slow down price adjustment of illiquid stocks: doubling the proportion of ISO volume on an announcement day results in a 78-minute delay in the adjustment of illiquid stocks relative to its benchmark level of 4 hours and 40 minutes when the level of trading aggressiveness remains constant. This overall negative effect of aggressive trading is more pronounced after positive earnings surprises, when aggressive trading is largely uninformative. After negative earnings surprises, when the majority of aggressive trades is submitted in the direction of the earnings surprise, the impact is less pronounced and no longer statistically significant. Interestingly, large decreases in trading aggressiveness can be even more harmful for illiquid stocks. With low trading aggressiveness, price changes of illiquid stocks are not sufficiently quick, which slows down the adjustment process.

This paper contributes to the on-going debate on the efficiency of financial markets. Specifically, it examines how the investors' trading process directly influences price

[4]Note that only changes in trading aggressiveness, as opposed to its levels, are suitable for the analysis of its effect on the speed of price adjustment. The reason is that the adverse effect on intraday volatility, and thus on the price stabilization process, only arises if the proportion of aggressive trades actually increases. By contrast, if trading aggressiveness is high, but stays at its pre-announcement level, there is no additional increase in the intraday volatility of a stock. In fact, the speed of price adjustment might be quicker for this stock than for a stock that experiences a rise in its intraday volatility due to the increased use of aggressive orders on the announcement day.

[5]I prefer the volatility criterion over measuring abnormal returns or the serial correlation in returns, because it covers both stages of price adjustment: the initial price reaction and the subsequent stabilization period.

adjustment. There is a vast amount of literature that investigates investor trading around information releases.[6] Surprisingly, the overlap between this literature and the price adjustment literature is relatively small.[7] To the best of my knowledge, only two studies exist that examine the relation between the trading process and the speed of price adjustment after information releases. Woodruff and Senchack (1988) find that stocks with large positive earnings surprises experience quicker adjustments than stocks with large negative earnings surprises. They further show that a large number of smaller trades occurs after positive earnings surprises and relatively few but larger trades after negative earnings surprises. However, they do not establish the causal relation between differences in trading processes and the speed of price adjustment. Ederington and Lee (1995) examine the short-run dynamics of price adjustment in interest rate and foreign exchange futures markets. The main finding of their study is that prices adjust in a series of small price changes, and not in few large price jumps, which also suggests that there is intensive trading immediately after an information release. Whereas both of the previous studies concentrate mainly on trade size and transaction frequency, the main focus of this paper is the effect of investors' trading aggressiveness, disclosed by their preference for the speed of order execution, on the price adjustment process.

Following the pioneering work of Chakravarty et al (2010), this paper also sheds light on the use and characteristics of intermarket sweep orders on the current financial markets. In addition to Chakravarty et al (2011a), who analyze changes in market breadth and daily trading aggressiveness on an announcement day, I investigate intraday changes in the use of aggressive orders. Further, I examine the informativeness of ISO trades by testing whether the proportion of ISO volume increases more in the direction of the earnings surprise right after an announcement release.

The remaining part of the paper is organized as follows. Section 2 provides details of the relevant institutional framework and develops the main hypotheses of this study.

[6] One of the first studies to analyze investor trading around information releases is Lee (1992), which examines differences in the clustering of small and large trades around earnings announcements. Recent studies examine the informativeness of institutional (Ali, Klasa, and Li (2008)) and individual trades (Kaniel, Saar, and Titman (2008), Kaniel et al (2012)) around earnings announcements. Also, Sarkar and Schwartz (2009) document a post-announcement increase in two-sided trading, especially when the news surprises are large.

[7] Prior empirical studies on the speed of price adjustment investigate the duration of the adjustment process for different announcement types (Patell and Wolfson (1984) for earnings announcements; Ederington and Lee (1993) for macroeconomic releases; Busse and Green (2002) for releases of analysts' opinions; Brooks, Patel and Su (2003) and Coleman (2011) for unanticipated events) and relate it to the degree of earnings surprise (Jennings and Starks (1985)), firm and report characteristics (Defeo (1986), Damodaran (1993)), timing of an announcement (Francis, Pagach, and Stephan (1992)), and differences in market structures (Greene and Watts (1996), Masulis and Shivakumar (2002)).

Section 3 describes the construction of the data set. Section 4 analyzes the use and characteristics of aggressive orders in the base period and around earnings announcements. Section 5 investigates how abnormal trading aggressiveness affects the speed of price adjustment after an announcement release. Section 6 briefly concludes.

2 Institutional Background and Hypothesis Development

2.1 Overview of Intermarket Sweep Orders

On August 29, 2005, the Securities and Exchange Commission (SEC) adopted a new set of rules, known as the Regulation National Market System (Reg NMS). The SEC designed the new regulation to modernize US equity markets and to promote their efficiency. Due to technical difficulties with the implementation of several changes required by this new regulation, markets achieved full compliance with Reg NMS first in October 2007.[8]

The most important change introduced by Reg NMS is the adoption of the Order Protection Rule (Rule 611) that requires execution of any incoming order at the best available price. The best available price is defined as the lowest ask or the highest bid price quoted over the previous one second among all equity trading venues in the US. If the trader sends a limit order to a venue that does not currently quote the best price, then this venue has to re-route the order to the venue with the best price. The Order Protection Rule caters mainly to the interests of retail investors. The best-price execution guarantee increases the retail investors' confidence and decreases their search costs for the best available price. Further, protection of the best-priced limit orders minimizes the investors' transaction costs, because the number of trade-throughs automatically declines.[9]

Although appealing to retail investors with a long-term investment horizon, the Order Protection Rule is less attractive for short-term and institutional investors. Suppose an institutional investor wants to sell 3,200 shares at a price not lower than \$10.67. For simplicity, suppose only two trading venues exist: A and B. Figure 1 shows the bid sides of limit order books in two venues. The first column shows the currently quoted bid prices, the second column indicates the number of shares available at each price for

[8] See Regulation NMS, SEC Release No. 34-51808.

[9] A trade-through occurs when the best available bid or the best available offer quotation is ignored, or in other words, "traded-through".

Figure 1: **Bid Side of Limit Order Book**

Price	Shares A	Shares B
\$10.75	500	
\$10.73		500
\$10.70	2,000	
\$10.67	3,500	
\$10.66		3,000

venue A and the third column displays the corresponding number of shares for venue B.[10] Assume that an investor submits his order to A. However, A's depth at the best available quote, \$10.75, is too small for the order to be fully executed: only 500 shares can be sold at the best price. Venue B quotes the next best bid price at \$10.73. Under the Order Protection Rule the outstanding part of the order (2,700 shares) has to be re-routed by venue A to venue B. After an execution of 500 shares at \$10.73 on venue B, the remaining part (2,200 shares) has to be re-routed to A again. However, re-routing takes time and the best bid offer can change while the order is being re-routed. Thus, the execution of large-sized orders under the Order Protection Rule takes longer and might end up at an inferior average price as compared to having the whole order executed at a single venue.

To avoid such situations, the Order Protection Rule makes an exemption for a specific order type, an intermarket sweep order (ISO). An ISO is a marketable limit order (Immediate-or-Cancel) and it provides an opportunity for institutional investors to trade large blocks quickly. Specifically, when an ISO arrives at a particular trading venue, it is executed as if this venue stands alone, ignoring the other venues. An ISO simply walks down the limit order book until either the order is completely filled or the limit price of the order is reached (the outstanding part of an ISO is then canceled). Importantly, there is no re-routing requirement, even if some parts of the order are executed at inferior prices as compared to the best national bid offer. To comply with the principles of the Order Protection Rule, an investor submitting an ISO is obliged to send additional limit orders, also marked as ISOs, with the same limit price to all other venues quoting the stock. The size of these additional ISOs should equal the

[10]Note that total depth at each price is equal to the sum of the number of shares quoted at this price and the cumulative number of shares quoted above this price for the bid side of the book (or, equivalently, below this price for the ask side of the book). Thus, total depth for P = \$10.70 on trading venue A equals 2,500 shares (500 shares quoted at \$10.75 and additional 2,000 shares quoted at \$10.70).

total number of shares available at quotes superior to the limit price at the time of the submission of the ISO. Therefore, an ISO represents a series of marketable limit orders with the same limit price sent across all trading venues quoting the stock. The total size of all simultaneously sent ISOs equals the total number of shares available at prices better than the indicated limit price plus any additional number of shares at the limit price.[11]

Suppose that an institutional investor wants to sell another 3,200 shares at the limit price of $10.67 with an ISO. Thus, the investor sends two limit orders, marked as ISO, with the same limit price of $10.67 simultaneously to both venues, A and B. The total size of the order is then optimally split between the two venues: an ISO sent to A has the total size of 2,700 and an ISO sent to B has a total size of 500. Since trading venues can recognize both orders as ISOs, they do not re-route either of them. Both venues instantaneously execute ISOs against the outstanding orders up to a limit price of $10.67. An investor instantly sells 3,200 shares and the new best price drops to $10.67 on venue A. Note that the institutional investor satisfies its obligations with respect to the Order Protection Rule because the investor has extracted all available shares that are quoted at prices better than $10.67 from both venues.

2.2 Hypothesis Development

Speed of price adjustment. Prior empirical studies document an increase in trading aggressiveness, measured as the proportion of ISO volume, following companies' information releases.[12] What implications does an increased use of ISOs have on the speed of price adjustment? With their ability to sweep liquidity almost instantly up to a particular price level, ISOs on average produce a higher change in the best quoted bid/ask price (*the price impact*) *within a given trading interval*, as compared to the standard limit order. To illustrate this point, assume that if an investor trades one share, then the best quoted bid/ask price changes by σ. In other words, *the price impact per share traded* equals σ. The trading day consists of a finite number of T intervals. During

[11] Paragraph (b)(30) of Rule 600 gives a formal definition of an intermarket sweep order as a limit order that satisfies the following requirements: (1) when routed to a trading venue, the limit order is identified as an intermarket sweep order; and (2) simultaneously with the routing of the limit order identified as an intermarket sweep order, one or more additional limit orders, as necessary, are routed to execute against the full displayed size of all protected quotations with a superior price.

[12] Chakravarty et al (2011a) report an increase in the proportion and volume of ISOs after earnings announcements. Lei and Li (2010) document the increased use of ISOs after the erroneous information on a bankruptcy announcement of the United Airlines on September 8, 2008.

a given interval *t,* an order can either be submitted to one trading venue (or several trading venues in the case of an ISO), be (fully or partially) executed at one of the venues, or be re-routed from one venue to another.

Suppose that a standard limit order and an aggressive limit order of an identical size s and with an identical limit price are submitted in t. In *t+1,* they arrive to the market and are ready for execution. Since the aggressive order is split at t across different exchanges as a series of limit orders, these exchanges do not need to search for the best quoted prices. Instead, all of the ISOs get immediate executions across all exchanges and the total size s of the aggressive order is executed at *t+1.* The full price impact of the aggressive order, $\sigma \cdot s$, is then realized within one trading interval *t+1.*

There are three possible execution scenarios for the standard limit order:

1) If the investor sends the limit order to the exchange with the best price quotes and the number of shares available at the best quotes is greater than *s,* then the venue fully executes the limit order. In this case, the limit order also produces the full price impact, $\sigma \cdot s$, within *t+1.*

2) If the investor sends the limit order to the exchange that does not quote the best price, it searches for the exchange with the best available quotes and re-routes the order to that exchange. No shares are executed and the price impact for *t+1* equals 0.

3) If the investor sends the limit order to the exchange with the best price quotes, but the number of shares available at the best quotes, y, is smaller than *s* ($y < s$), then the exchange only executes y shares and re-routes the outstanding part of the order, $s - y$, to another exchange with the next best available price. The price impact within *t+1* equals $\sigma \cdot y < \sigma \cdot s$.

Dependent on the liquidity of the stock, some scenarios are more prevalent than others. For example, for liquid stocks, the first scenario probably dominates, because there is large depth at each price level for these stocks. For illiquid stocks with a low number of shares available at each price, the last scenario occurs more frequently. However, on average, the price impact of a standard limit order is lower than the price impact of an aggressive order within *t+1*, because the full price impact does not get necessarily realized within one trading interval.

Consider the previous numerical example. Figure 2 summarizes the number of shares executed and the price impact of both orders in each trading interval. Price impact is calculated as the difference between the best bid price prior to the execution and the best bid price after the execution.

Note that in *t=1* the price impact of the standard order equals only \$0.02 when

Figure 2: **Price Impact Interval-by-Interval: Limit Order versus ISO**

		Limit order				**ISO**			
t	Action	Shares executed	Best Price before	Best Price after	Price Impact	Shares executed	Best Price before	Best Price after	Price Impact
0	Submission								
1	Execution	500	\$10.75	\$10.73	\$0.02	3,200	\$10.75	\$10.67	\$0.08
2	Re-routing								
3	Execution	500	\$10.73	\$10.70	\$0.03				
4	Re-routing								
5	Execution	2,200	\$10.70	\$10.67	\$0.03				
	Total	3,200			\$0.08	3,200			\$0.08

the venue executes the first 500 shares at the best available price, whereas the price impact of the aggressive order, \$0.08, is fully realized, because the total size of the order (3,200 shares) is immediately executed at both venues. If the limit order book does not change over time, the cumulative price impact of both orders is the same after t=5. The standard limit order just takes a longer time to execute because of the re-routing between the two different exchanges in search of the best execution price.

Since an aggressive order has on average a higher price impact within a given trading interval, the higher proportion of aggressive orders in the order flow subsequent to an announcement release enables quicker price movements within short time intervals. Quicker price movements are beneficial for price adjustment if the majority of traders are informed in the following sense: they have already correctly processed new information and know the true equilibrium value of a stock. They can then purchase the stock if it is undervalued or sell the stock if it is overvalued, pushing the stock price towards its new equilibrium value. In this case, an increase in trading aggressiveness might speed up price adjustment due to a quicker movement of the price in the correct direction.

However, quicker price movements might also slow down the adjustment process if the majority of aggressive traders are uninformed, in the sense that they do not observe the true equilibrium value of a stock and can only form their subjective beliefs about it. Some uninformed investors will purchase the stock and push the price temporarily upwards, whereas the other uninformed investors will sell the stock and push the price downwards. As the stock price continuously experiences quick upward changes, followed by quick downward changes, it is constantly over- and undershooting its true equilibrium value. Thus, large increases in aggressive trading by uninformed investors with

heterogeneous beliefs produce additional abnormal volatility and make the stabilization of a price at its new level harder.

Overall, the positive effect of quicker price movements towards the new equilibrium value should dominate in situations with the higher proportion of informed traders, whereas the negative effect of increased intraday volatility should dominate when the majority of aggressive traders are uninformed and have heterogeneous beliefs about the true value of the stock.

Liquid versus illiquid stocks. Does the influence of trading aggressiveness on the speed of price adjustment differ for stocks with high and low liquidity? Since illiquid stocks have a lower depth of the limit order book at each price level (their limit order book is "thinner"), *the price impact per share traded* is overall higher for these stocks.

Importantly, *the difference in price impact within a given trading interval* between an aggressive order and a standard order is higher for an illiquid stock than for a liquid stock. The effect of the aggressive order is larger on the price of an illiquid stock, because a larger number of shares is executed within a given trading interval and, additionally, the price changes by a larger amount per each traded share. Basically, the effect of a thinner book for illiquid stocks is additionally multiplied with the effect of faster trading with aggressive orders, and an aggressive order thus goes faster through a thinner limit order book. Therefore, I expect the positive and negative effects of increased aggressive trading on the speed of price adjustment to be more pronounced for illiquid stocks.

3 Data and Sample Construction

3.1 Earnings Announcements Sample

The data source for the earnings announcements is the Institutional Brokers Estimate System (I/B/E/S) database. I collect announcements between January 2006 and December 2009 that happen within the trading hours of US equity trading exchanges (9:30 a.m. to 16:00 p.m. EST).[13] Each record has an exact date and a time stamp (up to a minute). Further, I require that each firm exists in the intersection set of I/B/E/S and CRSP. Table 1 provides details of the sample construction.

[13] I use earnings announcements from the pre-Reg NMS period to form the control group of stocks, needed for the difference-in-differences analysis.

[Insert Table 1 approximately here]

The initial sample comprises 10,334 announcements by 3,361 firms. I omit 647 announcements by 88 firms for which a stock is not traded on the announcement day, and another 967 announcements by 267 firms for which intraday transaction data are not available. Following Jegadeesh and Titman (1993), I further eliminate very illiquid stocks for which the closing price is less than $5 at the beginning of the base period. The reasoning behind this elimination is that the large deviations in intraday volatility of these stocks on their announcement days might be biased upwards by the virtue of their low price levels. Excluding days with multiple announcements and announcements with less than 40 days of trading data previously available leaves 5,944 announcements by 2,307 firms.[14] To ensure that the differences in results between the pre-Reg NMS period and the post-Reg NMS period are not driven by differences in the characteristics of the underlying stocks, I require that each stock in the sample has at least one announcement in each period. The final sample consists of 3,613 announcements by 675 firms, out of which 1,818 announcements happen prior to the adoption of Reg NMS and 1,795 afterward.

One of the requirements for the data set's construction is that an announcement should happen within trading hours. Out of the 6,536 firms for which I/B/E/S reports earnings announcement releases over 2006 to 2009, 3,175 firms do not announce within trading hours. The remaining 3,361 firms constitute the initial sample out of which 58 firms release their earnings information exclusively within trading hours and 3,303 announce both within and outside trading hours. Overall, firms announcing both within and outside trading hours are smaller than the firms announcing only outside trading hours, with the median market capitalization of $239 million and $482 million, respectively (results not tabulated). Even though there is a bias towards smaller firms, the initial sample still covers more than 50% of all of the firms with earnings announcement releases. Table 2 summarizes the main firm characteristics in the final sample and the initial sample. All variable definitions are in the appendix.

[Insert Table 2 approximately here]

Since I exclude small and illiquid stocks with closing prices below $5 from the final sample, the median firm in this sample has a larger market capitalization of $256 million, as compared to $239 million of the median firm in the initial sample. As expected, the

[14] I require at least 40 days of trading data to be available prior to an announcement, because I use these days to calculate values in the base period that consists of days [-38;-2].

median firm in the final sample is more liquid than the median firm in the initial sample, as measured by the daily relative spread and the daily Amihud measure.[15]

3.2 Intraday Transaction and Quote Data

The source for the intraday transaction data is the NYSE Transaction and Quote database (TAQ). In the first step, I extract data on the number and trading volume executed with the ISOs and standard limit orders (non-ISOs) for each stock in the final sample on their announcement days as well as 40 trading days preceding the announcements. The ISOs are marked with the code "F" in the condition field of the TAQ database. The base period consists of 39 trading days preceding an announcement day, starting on day -40 and ending on day -2. I collapse transaction-by-transaction data over 15-minute intervals and extract the number of trades and traded volume in each 15-minute interval separately for the ISOs and non-ISOs. I use a modified Lee and Ready's (1991) algorithm to identify the direction of a trade, with the bid (B_t) and the ask quote (A_t) that prevail one second before the trade takes place.[16]

The quoted relative spread for a transaction is defined as the difference between the corresponding ask and the corresponding bid, scaled by the midpoint price ($RelSpr_t = (A_t - B_t)/Q_t$). The midpoint price ($Q_t$) is calculated as the average of the prevailing bid and ask quotes ($Q_t = \frac{A_t+B_t}{2}$). I set the observations with $RelSpr > 0.5$ to the missing values. The effective relative spread of each transaction is calculated as twice the absolute difference between the transaction price and the midpoint price, scaled by the midpoint price ($EffSpr_t = 2\left|P_t - Q_t\right|/Q_t$). Observations with $EffSpr > 0.5$ are also set to missing values. The price impact of each trade after five minutes is defined as $PrcImp_t = 2\left|Q_{t+5} - Q_t\right|/(Q_t \cdot w_t)$ where Q_{t+5} represents the midpoint price for a stock after five minutes (300 seconds), and w_t is the size of the transaction (in shares). Note that this measure is similar to the daily Amihud measure, but it is calculated on an intraday basis.

The intraday one-minute returns are computed from the closing midpoint price for each minute from the TAQ Consolidated Quotes database. Closing midpoints better serve the purposes of the price adjustment analysis, because they exclude the bid-ask bounce that is present in the transaction prices.

[15] The Amihud (2002) measure is defined as the ratio of the daily absolute return to the dollar trading volume on that day: $Illiq_{i,t} = \left|Ret\right|_{i,t}/Dollar\,Volume_{i,t}$.

[16] Henker and Wang (2006) consider this procedure to be more appropriate compared to the classical Lee and Ready (1991) five-second rule. Bessembinder (2003) tries zero- to thirty-second delays in increments of five seconds and does not find any differences in the results.

4 Trading Aggressiveness around Earnings Announcements

Definition of Trading Aggressiveness. I define trading aggressiveness as the proportion of total volume traded with ISOs within a particular time interval (the proportion of ISO volume, $\%ISOVolume$). Daily trading aggressiveness is the proportion of daily volume that is executed through ISOs. Intraday trading aggressiveness is measured as the proportion of ISO volume over a respective time interval within a day, for example 15 minutes, 1 hour etc.[17] In the remainder of the paper I use the terms "trading aggressiveness" and "trading with aggressive orders" interchangeably.

The median proportion of ISO volume in my sample is 36%. However, the variation is quite significant with 22% of the volume traded with ISOs for firms in the lowest decile and 56% in the highest decile (not tabulated).

Trading characteristics of aggressive orders. Panel A of Table 3 summarizes the differences in the characteristics of ISOs and non-ISOs in the base period and in the hours immediately following the release of an earnings announcement.

[Insert Table 3 approximately here]

Columns 1 and 2 display the bootstrapped means for the ISOs and non-ISOs from the base period, correspondingly.[18] Columns 3 and 4 report the cross-sectional mean of the respective variables starting from an announcement release until the end of the trading day. Column 5 displays the difference-in-differences (or simply the difference between the base period and the event day for variables, calculated as proportions) and tests their significance with a standard t-test.

The proportion of trades, executed with aggressive orders, $\%Trades$, equals 40.8% in the base period. It increases significantly by 4.6% in hours immediately following an information release. The proportion of the total volume executed with aggressive orders, $\%Volume$, (37.8%) is lower than $\%Trades$ in the base period, but it also significantly

[17] The proportion of the total number of trades executed with ISOs is highly correlated with the proportion of ISO volume (correlation coefficient of 93%). None of my results is materially affected if I use the proportion of ISO trades to measure trading aggressiveness.

[18] Since the base period is rather short (38 days) and proportions of the number of trades and of their volume are not normally distributed, I estimate their means with a bootstrap procedure. Specifically, I draw with replacement one observation from the base period that happened between the time of an announcement release and the end of the trading day for each stock-announcement and repeatedly calculate the mean across all stock-announcements in this bootstrapped sample. I repeat this step for 1,000 bootstrapped samples.

increases to 42.4% on announcement days. The reason for the lower proportion of ISO volume is the overall smaller size of the ISOs. The average size of an ISO in the base period equals 176 shares, as compared to 256 shares for a non-ISO.[19] Overall, the ISO characteristics in my sample are similar to the ISO characteristics in the Chakravarty et al (2010) sample.[20]

Interestingly, investors use ISOs approximately as much for purchases as for sales. The proportion of ISO purchase volume, $\%Purchases$, and the proportion of ISO sales volume, $\%Sales$, both increase significantly by around 4% on announcement days. Further, the effective relative spread, $EffSpr$, is marginally lower for ISOs in the base period, 1.73%, as compared to 1.82% for non-ISOs. However, it does not differ significantly from the non-ISO effective spread on event days. As liquidity around information releases declines, all traders, including uninformed ones, become more aggressive, and the effective relative spread increases accordingly to the level of non-ISOs. The price impact of ISO trades, $PrcImp$, is higher than the price impact of non-ISOs, and even more so in hours following an information release (the difference-in-differences equals 0.11% and is statistically significant at the 5% level). This finding is important, because it provides the first supportive evidence for the assumption that ISO trades have a higher price impact within a given trading interval, as compared to non-ISO trades.

Next, I examine changes in the use of aggressive orders at the intraday level. Figure 3 displays mean percentage deviations in the proportion of ISO volume throughout an announcement day. The deviations from the bootstrapped means are measured in 15-minute intervals relative to the 15-minute interval with an earnings announcement release (interval 0). The dashed line shows the 1% significance level for the mean percentage change in the proportion of ISO volume, which is equal to 3.8%.

[Insert Figure 3 approximately here]

The proportion of ISO volume experiences a jump of up to 15% ($\%ISOVolume = 43.47\%$) in the first 15 minutes after an information release. Afterward, it steadily decreases, but never drops below the 1% cutoff value till the end of the trading day.

The reasons for an increase in trading aggressiveness on an announcement day are twofold. First, investors have different rates of information processing. Those investors

[19] The size of an ISO is smaller, because the TAQ database does not record a cumulative size for all ISOs sent simultaneously across all exchanges, but rather the size of each individual order sent and executed on a particular stock exchange.

[20] The proportion of ISO trades is 46% and the proportion of ISO volume equals 41% in their sample. The average size of an ISO equals 178 shares and is also significantly smaller than the average size of a standard limit order.

who are able to process new information more quickly try to exploit their advantage. The 15% jump immediately after a release indicates the increase in pressure from traders with quicker rates of information processing. Second, uninformed investors might also trade more aggressively because of the decreasing liquidity supply around earnings announcements. Chakravarty et al (2011a) provide empirical evidence in support of this explanation.

Intraday analysis of the effective relative spread and price impact. The results from Panel A of Table 3 confirm that the ISO trades have an overall higher price impact within a given trading interval than the non-ISO trades. However, I expect the difference in the intraday price impact between the ISO trades and non-ISO trades to be higher for illiquid stocks, because an aggressive order goes faster through a thinner limit order book of an illiquid stock, which produces an even higher price change.

To investigate this hypothesis more closely, I report the intraday price impact of ISO trades in post-announcement hours separately for liquid and illiquid stocks (Panel B of Table 3). The stock is classified as liquid if its daily quoted relative spread is above the median for all of the stocks in the sample in the base period, and it is classified as illiquid otherwise. The last line in Panel B of Table 3 confirms this prediction, because the difference in the intraday price impact between the ISO and the non-ISO trades for illiquid stocks is higher than the corresponding difference for liquid stocks by 0.45% and is statistically significant at the 1% level. Note that investors trade illiquid stocks more aggressively in the post-announcement hours than liquid stocks, because the proportion of their volume traded with aggressive orders (43.4%) exceeds the proportion of ISO volume for the liquid stocks by a significant 2%.

Table 4 additionally investigates differences in the effective relative spread and the intraday price impact between the ISO and the non-ISO trades in a multivariate setup. The main variable of interest is the *ISO,* which equals one for ISO trades, and zero otherwise. One observation represents a ten-minute trading interval for a stock. All models are panel OLS regressions and include firm-, year-, daytime- and weekday-fixed effects. In addition, I control for the inverse of the mean stock price in a ten-minute period, which is mechanically related to the two dependent variables; the total volume executed within a 10-minute trading interval; and the listing exchange of a stock.

[Insert Table 4 approximately here]

The effective relative spreads of the ISO and non-ISO trades exhibit no significant differences in the base period as well as on announcement days, as captured by the

indicator variable ISO and its interaction with the indicator variable *Event* that denotes the announcement day. These results are in line with prior univariate analyses and continue to hold if I additionally control for the liquidity of a stock with an indicator variable *Illiquid* (Model 2). All control variables have their expected signs.

In line with prior findings, the intraday price impact is higher for the ISO trades in the base period and even more so on announcement days. However, the latter effect disappears if I add the indicator variable *Illiquid*, which means that an additional increase in the intraday price impact on announcement days is driven by illiquid stocks, consistent with the univariate results from Table 3. After controlling for liquidity as well as other control variables, the additional intraday price impact of an aggressive order constitutes 0.187% for an illiquid stock, which is statistically and economically significant (e.g., 3.74 cent for an average illiquid stock with a price of $20 and a quoted spread of 96.4 cent).

Informativeness of ISO trades after earnings announcements. Prior results show that trading aggressiveness increases significantly in the hours following earnings announcement releases. The next step is to analyze whether the increased use of aggressive orders in post-announcement hours represents informed or uninformed trading. Recall that the effect of trading aggressiveness on the speed of price adjustment depends on the informativeness of the ISO trades. The effect is positive (higher trading aggressiveness speeds up price adjustment) if informed investors submit the majority of the ISOs and trade in the direction of the new equilibrium value. The effect is negative (higher trading aggressiveness slows down price adjustment) if the ISOs are mostly submitted by uninformed investors who are just as likely to buy or sell a stock.

I analyze the informativeness of ISO trades by testing whether the proportion of ISO volume increases more in the direction of the earnings surprise. For positive earnings surprises, aggressive trading is more informative if the change in the proportion of ISO buy volume ($\Delta ISOBuyVol$) is overall higher than the change in the proportion of ISO sell volume ($\Delta ISOSellVol$). For negative earnings surprises, the opposite relation should hold. I measure an earnings surprise as a 24-hour stock return after an announcement release.[21]

If prices overshoot, then trading in the opposite direction of the earnings surprise is also informative. For this reason, I additionally classify trades on an intraday basis: I define an ISO trade as informative if it is buyer-initiated and the current price is

[21] The results do not differ materially, if CAR(0;1) or I/B/E/S analyst earnings forecasts are used to measure earnings surprises. In the case of analyst earnings forecasts, I lose around 50% of observations in my final sample due to missing data in I/B/E/S.

below the equilibrium price, or if it is seller-initiated and the current price is above the equilibrium price. The proxy for an equilibrium price is the price in 24 hours after an announcement release, which is reasonable to assume, because the short-term price adjustment happens on average 2.5 hours after an announcement release (as the next section documents). I find that after positive earnings surprises 80.7% of all informative trades are buyer-initiated and after negative earnings surprises 86.8% of all informative trades are seller-initiated. None of my results is materially affected if I define informativeness of an ISO trade on an intraday basis.

In the first step, I examine the imbalance between the proportions of ISO buy and ISO sell volumes on announcement days. Figure 4 displays both proportions for each 15-minute event interval relative to the 15-minute interval with an earnings announcement release (interval 0). The dashed line marks the event interval 0.

[Insert Figure 4 approximately here]

Panel A shows the imbalance in the proportions of ISO volumes for positive earnings surprises. Interestingly, the proportions of the ISO sell and ISO buy volumes increase in the first hour after an announcement release. The proportion of the ISO buy volume begins to dominate only after two hours. These preliminary results suggest that the majority of ISO trades are mostly uninformative in the first hour after a positive earnings announcement release. Although investors realize that higher earnings is good news, their initial opinions might diverge on how good this news is. As time passes by, traders correctly process the information from an announcement release and ISO trades increase their informativeness. The situation is different for negative earnings surprises (Panel B). The proportion of the ISO sell volume experiences a jump of up to 3% (from 47% to 50%) in the first 15 minutes after an announcement and significantly dominates the proportion of ISO buy volume for at least three hours after an announcement release. Thus, investors react quickly to the negative news and increase their aggressiveness on the sell side almost immediately.

Table 5 examines the informativeness of the ISO trades separately for the subsamples of liquid and illiquid stocks. In addition to the direction of the earnings surprise, I differentiate between large and small surprises. An earnings surprise is defined as large if a 24-hour stock return is above its median for positive earnings surprises and below its median for negative earnings surprises. The first column shows the number of hours since an announcement release. The remaining columns report the difference in means between the increases in the proportion of the ISO buy and ISO sell volumes for the corresponding hour:

$$\Delta = \Delta_{Buy} - \Delta_{Sell},$$

where $\Delta_{Buy} = \%ISOBuyVol_{Event} - \%ISOBuyVol_{Base}$, and $\triangle_{Sell}$ is calculated in a similar way.

[Insert Table 5 approximately here]

On average, investors increase their trading aggressiveness in the correct direction: they increase the proportion of the ISO buy volume by a larger amount if an earnings surprise is positive ($\Delta > 0$), and by a smaller amount if it is negative ($\Delta < 0$). As expected, the differences in proportions are higher for larger earnings surprises.

Consistent with Figure 4 (A), the ISO trades are quite uninformative in the first hour after a positive announcement release for both liquid and illiquid stocks. Over time aggressive trading becomes more informative, but none of the coefficients is statistically different from zero. For large positive surprises, an increase in the proportion of the ISO buy volume is on average higher and becomes statistically significant at the 10% level for liquid stocks four hours after an announcement release. For negative earnings surprises, the ISO trades are largely uninformative for liquid stocks, but they are strongly informative for illiquid stocks for up to five hours after an announcement release. All differences are negative and significant either at the 5% or the 1% levels. These findings suggest that a significant jump in the proportion of ISO sell volume immediately after an announcement release, observed in Figure 4 (B), is mainly driven by an increase in the aggressiveness of informed traders of illiquid stocks.

Overall, even though investors increase their trading aggressiveness mostly in the correct direction, ISO trades are largely uninformative for positive earnings surprises and are strongly informative for negative earnings surprises, but only for the subsample of illiquid stocks.

5 Trading Aggressiveness and the Speed of Price Adjustment

How does an increase in trading aggressiveness after an earnings announcement release influence the speed of price adjustment to the new equilibrium value? An increase in trading aggressiveness by traders with quicker rates of information processing might increase the speed of the initial price reaction, by pushing the price more quickly towards its new equilibrium value. However, if the majority of the aggressive traders are uninformed, because they do not observe the new equilibrium value, their increased trading aggressiveness might also prolong the subsequent stabilization stage and unnecessarily increase the post-announcement intraday volatility. Figure 5 provides evidence in support of both statements. Panel A shows that stocks with higher increases in trading aggressiveness on announcement days experience larger jumps in their cumulative absolute returns during the first minutes after the information releases. However, these stocks also have higher increases in their intraday volatilities, which persist up to four hours after the announcement releases (as reported by Panel B). This section examines which of these two countervailing effects dominates.

The definition of the end of the price adjustment process. The speed of price adjustment can be theoretically measured as the difference in time between an announcement release and the time when the price reaches its new equilibrium value. Since the new equilibrium price level is not observable, I have to empirically determine the time period when the price ends its adjustment process. I consider that the price ends its adjustment process if the intraday volatility returns to its pre-announcement level. Prior studies by Patell and Wolfson (1984) and Jennings and Starks (1985) analyze post-announcement abnormal returns and abnormal serial correlations in price changes, in addition to abnormal volatility. However, the volatility criterion is more appropriate for this study, because it captures both stages of price adjustment: the initial price reaction as well as the subsequent period of price stabilization.[22]

Andersen et al (2001) show that the realized variance, calculated as the sum of the squared high-frequency returns over a particular time interval, represents the most unbiased and efficient estimator of daily as well as intraday volatilities. As illustrated

[22]Patell and Wolfson (1984) and Jennings and Starks (1985) show that abnormal returns disappear in 5 to 15 minutes after an earnings announcement release. However, abnormal volatility of intraday returns persists for several hours and can even extend to the following trading day. The recent study by Brooks, Patel and Su (2003) provides similar evidence for unanticipated events with abnormal returns lasting for 15 minutes and abnormal variance for at least three hours after an event.

by Martens and van Dijk (2007), the realized variance is also robust in the presence of infrequent trading and non-trading intervals. I calculate the realized volatility as the standard deviation of the sum of the squared one-minute closing midpoint returns within each five-minute interval according to the following formula:

$$RV_{ti} = \sqrt{\sum_{j=1}^{5} (log\, C_{ti,j} - log\, C_{ti,j-1})^2},$$

where $C_{ti,j}$ represents the closing midpoint of a minute j within a five-minute interval i on day t. Further, I use the non-parametric test, proposed by Smith et al (1997), to compare the realized volatility within each five-minute interval during an announcement period (event days 0 to 2) with the realized volatility within the same five-minute interval in the base period (event days -40 to -3). Volatility is considered to be abnormal if it exceeds the 75% cutoff value in the same five-minute period calculated over days $[-40; -3]$. I also report the multivariate results for a more conservative definition of the abnormal volatility for which volatility is defined as abnormal if it exceeds the median volatility in the same five-minute period on the non-announcement days.[23]

To identify the end of the adjustment period, I order all intervals in the event window relative to the first five-minute post-announcement interval (interval 0). The ordering is consecutive for all days in the event window. For example, if an announcement time was 3 p.m. on day 0, then a period from 9:30 a.m. until 9:35 a.m. on the next day is numerated as period 13. The price ends its adjustment in the first interval for which the realized volatility is no longer abnormal.[24]

Univariate results. Panel A of Table 6 displays the distribution of the length of price adjustment periods (in minutes) across the pre- and post-Reg NMS periods, separately for the subsamples of liquid and illiquid stocks. Thus, the median length of a price adjustment period for a liquid stock prior to the Reg NMS is 125 minutes after an announcement release. After the Reg NMS the median adjustment time for liquid stocks significantly decreases by 25 minutes as reported by the non-parametric Mann-Whitney test. Surprisingly, the median length of the price adjustment period

[23]The non-parametric test of Smith et al (1997) is more appropriate for high-frequency intervals, especially for illiquid stocks with thin trading. Prior studies by Patell and Wolfson (1984) and Woodruff and Senchack (1988) use parametric tests to compare distributional properties between announcement and non-announcement samples, because they use much longer one-hour sampling intervals.

[24]Patell and Wolfson (1984), Brooks, Patel, and Su (2003), Masulis and Shivakumar (2002), analyze the post-announcement volatility in a univariate setup and test up to which interval it exhibits significant increases, but they do not explicitly define the length of the adjustment period. In addition to 5-minute intervals, I use 10-minute, 15-minute and 30-minute intervals to identify the end of the adjustment period. All results stay robust and are available upon request.

for an illiquid stock (178 minutes or ca. 3 hours) does not change significantly in the post-Reg NMS period. The standard deviation of the length of the price adjustment period has even increased for these stocks, which suggests that the adjustment process has become quicker for some illiquid stocks in the post-Reg NMS period and slower for the other.

[Insert Table 6 approximately here]

To investigate this issue more closely, I sort all announcements into terciles of changes in trading aggressiveness on announcement days (TA1 - TA3) in the post-Reg NMS period. The TA3 comprises announcements with the highest increases in trading aggressiveness on event days, whereas the TA1 comprises stocks with the lowest increases.[25] To compare the change in the length of the adjustment period between two regulation regimes, I also assign "pseudo"-terciles of trading aggressiveness for all announcements in the pre-Reg NMS period. For this purpose, I calculate the median TA tercile for each stock after the Reg NMS and assign this TA tercile for all announcements of this stock that happen prior to the Reg NMS.[26] Panel B of Table 6 displays the median length of the adjustment period (in minutes) for each TA tercile. The last two rows report the p-values of the Mann-Whitney test on the equality of medians across different terciles of trading aggressiveness.

Consistent with the previous results from Panel A, the price adjustment process is quicker in the post-Reg NMS period for each TA tercile in the sample of liquid stocks. However, there is no significant relation between an increase in trading aggressiveness and the speed of price adjustment for these stocks. By contrast, this relation has a striking U-shape in the sample of illiquid stocks, which gets even more pronounced in the post-Reg NMS period. Whereas the adjustment time for illiquid stocks in the TA1 group decreases in the post-Reg NMS period, it stays constant for stocks with moderate increases in trading aggressiveness (TA2) and even increases for stocks with excess trading aggressiveness in post-announcement hours (TA3). The 75-minute difference

[25] Recall that trading aggressiveness is measured as the change in the proportion of ISO volume traded after an announcement release relative to its mean in the base period ($\Delta ISOvol$). Although on average trading aggressiveness increases in hours after the release, changes in the proportion of ISO volume can take negative values for some stocks in the TA1 sample.

[26] Normally, there is almost no within-stock variation in liquidity and trading aggressiveness and I can correctly assign the "pseudo"-TA tercile for almost 90% of all of the stocks in my final sample. I omit the remaining 10% from the univariate analysis in Table 6, but add these observations later in my multivariate analysis.

in medians between the second and the third tercile of trading aggressiveness in the post-Reg NMS period is also statistically significant at the 5% level.

Figure 6 further illustrates the relation between the mean length of the price adjustment period, measured in minutes, and the mean change in the proportion of ISO volume in the subsamples of liquid and illiquid stocks.

[Insert Figure 6 approximately here]

Overall, the patterns are consistent with those reported in Table 6. Large increases in trading aggressiveness slow down the speed of price adjustment for illiquid stocks, but seem to have no effect for liquid stocks. A more surprising finding is that decreases in trading aggressiveness have different implications for liquid and illiquid stocks. Higher decreases in trading aggressiveness are beneficial for liquid stocks, but they slow down the adjustment process of illiquid stocks.

Regression analysis. In this subsection, I estimate the negative binomial regressions with the length of the adjustment period as the dependent variable.[27] The identification strategy is a difference-in-differences analysis, because I am interested in the effect of changes in trading aggressiveness on the speed of price adjustment after controlling for the differences in the speed of price adjustment in the pre-Reg NMS period. For this reason, all of the regressions include earnings announcements from the pre- and the post-Reg NMS period. Since each stock in the final sample has at least one announcement in each of the regulation periods, the results are not influenced by differences in the underlying subsamples.

Models (1) to (3) of Table 7 report the results for the benchmark definition of abnormal volatility: volatility is abnormal if the realized volatility lies in the upper quartile of the volatility distribution in the non-announcement period.

[Insert Table 7 approximately here]

The vector of the explanatory variables consists of the following variables: *Post Reg* that equals one if an announcement happens after the adoption of the Reg NMS, and zero otherwise; *Illiq* that equals one if the relative spread of the stock is above the median of all of the stocks in the sample, and zero otherwise; the interaction of the previous two variables, $Illiq \cdot Post\ Reg$; the positive change in the proportion of the

[27] Since the dependent variable is the number of five-minute intervals until the price ends its adjustment, it represents the count data. Thus, the sample consists of discrete values and is skewed to the right. Negative binomial regressions account for these problems and for the overdispersion present in the data.

ISO volume for liquid stocks, $Liq \cdot |\Delta ISOvol|_{\Delta>0}$; the positive change in the proportion of ISO volume for illiquid stocks, $Illiq \cdot |\Delta ISOvol|_{\Delta>0}$; and the two corresponding variables for negative changes in the proportion of the ISO volume. I examine separately the influence of the positive and negative deviations in the proportion of ISO volume on the length of the adjustment period, because the relation between trading aggressiveness and the speed of price adjustment might be non-monotonic (as suggested by the univariate results).

The vector of the control variables consists of the mean turnover on event days $[0; 2]$, *Turnover;* the average size of a firm that is calculated as the log of its market capitalization at the beginning of the base period, *LnMCap;* the stock market volatility on an announcement day that is measured by Chicago Board Options Exchange Market Volatility Index, *VIX*; and the absolute value of the earnings surprise, *Earn Surp.* I expect the coefficient for *Turnover* and *LnMCap* to be negative, because more frequently traded stocks should adjust more quickly to their equilibrium value. By contrast, higher stock market volatility on the announcement day and larger earnings surprises should slow down the adjustment process. I also add year-fixed effects and control for the weekday and the time of an announcement.

The benchmark value of the dependent variable equals the mean length of the price adjustment period for liquid stocks before the adoption of the Reg NMS (218 minutes or around 3.63 hours, according to Panel A of Table 6). All of the coefficients should be interpreted as relative changes to the length of the price adjustment period from this benchmark value: for one unit change in the explanatory variable, the difference in the logs of the expected counts of the dependent variable is expected to change by β. For example, the coefficient of -0.20 on the *Post Reg* means that the length of the price adjustment period has on average decreased by $e^{-0.20} - 1 = -0.18$ or 18% from the benchmark value for liquid stocks in the Post-Reg NMS period (from around 3.63 hours to around 3 hours). As expected, the price adjustment period is significantly longer for illiquid stocks by approximately 42%. It does not differ significantly between the two regulation subperiods. All control variables, except *LnMCap,* are significant and have their expected signs.

Consistent with the univariate results, the relation between trading aggressiveness and the speed of price adjustment is rather weak for liquid stocks: negative changes in the proportion of the ISO volume contribute to quicker price adjustment, whereas positive changes do not play a significant role. For illiquid stocks, this relation continues to display a pronounced U-shape, even if I add other control variables. A 100% change

in the proportion of the ISO volume slows down the adjustment process by 28% (ca. 78 minutes) for positive changes and by 36% (ca. 100 minutes) for negative changes from its mean value of 4 hours and 40 minutes. This change is statistically and economically significant.

Why do large decreases in trading aggressiveness have different implications for stocks with different levels of liquidity? Aggressive orders induce quicker price changes within a given time interval. Since liquid stocks are traded more frequently by definition, their prices adjust quickly, and thus, an additional increase in the speed of the price changes is not necessary. A decrease in trading aggressiveness speeds up the adjustment process of liquid stocks, because it leads to a reduction in the abnormal volatility and does not produce a negative effect on the speed of the price changes. By contrast, illiquid stocks are infrequently traded. Therefore, a large decrease in trading aggressiveness adversely affects the speed of their price changes and slows down the adjustment of the stock price towards its new equilibrium value.

Informativeness of ISO trades and the speed of price adjustment. The previously formulated hypotheses suggest that the negative effect of trading aggressiveness on the speed of price adjustment should dominate if investors who submit ISOs are largely uninformed and trade in different directions. In such a case, aggressive trades produce very quick upward price changes following purchase transactions and very quick downward price changes following sales transactions. Thus, an increase in aggressive trading raises the probability of price overshooting and intraday volatility of the stock. In the following, I test this hypothesis in the subsample of illiquid stocks, because, according to the previous results, trading aggressiveness has a large and significant impact on these stocks. Table 5 shows that aggressive trading is largely uninformative for illiquid stocks after positive earnings surprises, and it is strongly informative for these stocks after negative earnings surprises. Therefore, I expect the negative influence of excess trading aggressiveness on the speed of price adjustment of illiquid stocks to be stronger in the subsample of positive earnings surprises.

Models (2) and (3) of Table 7 present the results for the subsamples of the positive and negative earnings surprises, respectively. In line with previous expectations, the negative effects of trading aggressiveness for illiquid stocks dominate only in the subsample with positive earnings surprises. A 100% change in the proportion of ISO volume slows down the adjustment process of the illiquid stocks by 36% for positive changes and by 75% for negative changes. Thus, an extreme decrease in trading aggressiveness can be even more harmful than an excess increase in the situations when

majority of investors are uncertain about the new equilibrium value of an illiquid stock. A large decrease in trading aggressiveness might suggest that the majority of the investors are uninformed, and they prefer to stay out of the market, which increases the probability that the trading process freezes out completely. The negative effect of trading aggressiveness gets reduced and loses its statistical significance in the sample of negative earnings surprises, when ISO trades are on average more informative (Model 3).

Robustness checks. Models (4) to (6) of Table 7 repeat the previous analysis with a more conservative definition of abnormal volatility: volatility is defined as abnormal if the realized volatility exceeds its median level in the same five-minute period on non-announcement days. Although slightly lower in absolute value, all of the previous results for illiquid stocks still hold. The previous marginally significant effect of decreases in trading aggressiveness disappears for the subsample of liquid stocks, which again demonstrates that there is no significant impact of trading aggressiveness on the speed of price adjustment for these stocks.

Since the average price of the illiquid stocks, \$20.1, is lower than the average price of the liquid stocks, \$32.8, the larger deviations in the intraday volatility of the one-minute returns of the illiquid stocks on the announcement days might be just mechanical. Therefore, the lower price of the illiquid stocks could bias the adjustment time upwards and overestimate the influence of trading aggressiveness on the speed of the price adjustment of these stocks. To account for the price level of the illiquid stocks, I use the realized price range measure, proposed by Martens and van Dijk (2007):

$$RR_{ti} = \frac{(log\, H_{ti} - log\, L_{ti})^2}{4\, log\, 2},$$

where H_{ti} represents the maximum closing midpoint price within a five-minute interval i on day t and L_{ti} represents the corresponding minimum price. Models (1) to (3) of Table 8 report the results with the modified dependent variable. All of the previous findings are robust.

[Insert Table 8 approximately here]

Next, I measure the liquidity of the stock with the daily Amihud (2002) measure. An indicator variable *Illiq* now equals one if the mean Amihud measure of the stock in the base period is above the median for all of the stocks in the sample, and equals zero otherwise. Models (4) to (6) of Table 8 display the corresponding results, which are again consistent with those of Table 7.

Overall, the findings in this section show that the relation between trading aggressiveness and the speed of price adjustment is not significant for liquid stocks and exhibits a pronounced U-shape for illiquid stocks. Thus, both large increases and large decreases in the proportion of aggressive trades slow down the adjustment process of illiquid stocks. For excess increases in trading aggressiveness, the adverse effect of the additional intraday volatility dominates, especially after positive earnings surprises when the aggressive trading is overall uninformative. However, when the majority of ISO trades are submitted in the direction of the earnings surprise, the negative effect of the excess trading aggressiveness is reduced and becomes largely insignificant. Interestingly, although less common, large decreases in trading aggressiveness can be even more harmful for the adjustment process of illiquid stocks, because they prevent their stock price from moving towards its new equilibrium value and can even signal a complete freeze-out of the trading process.

6 Conclusions

This paper analyzes how abnormal trading aggressiveness after earnings announcement releases influences the speed of price adjustment of stocks on US financial markets. I measure trading aggressiveness as the proportion of volume that is traded with the most aggressive limit orders available, intermarket sweep orders, over a particular time interval. Intermarket sweep orders represent an exemption from the Order Protection Rule of the Regulation National Market System and are executed more quickly than other limit orders, but possibly at an inferior price. They produce larger intraday price impact and contribute to quicker price changes within a given time interval.

The major result of this study is that excess trading aggressiveness after earnings announcements is overall harmful to the speed of price adjustment of illiquid stocks. As compared to the pre-Reg NMS period, when aggressive orders were not yet available, the adjustment time after an earnings announcement release has increased for illiquid stocks with large deviations in the proportion of ISO volume. The effect is more pronounced after positive earnings announcements when aggressive trades are mostly conducted by uninformed investors who do not observe the new equilibrium value of the stock. Since uninformed investors are just as likely to buy or to sell, quick price changes in different directions unnecessarily increase intraday volatility and make the price stabilization process more difficult.

The findings in this paper suggest that the excessive use of intermarket sweep orders

produces adverse effects on the adjustment process of illiquid stocks after information releases. Thus, market efficiency for these stocks can be even further reduced in situations where traders become too aggressive - something, that needs to be taken into account by stock exchanges and market regulators if they are interested in the promotion of accurate and transparent prices.

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Appendix

Variable Definitions

Variable	Description	Source
$1/P$	The inverse of the stock price (in \$)	TAQ
$\Delta ISOvol$	The change in the proportion of daily volume that is executed with aggressive intermarket sweep orders (ISOs) after an announcement release relative to its mean in the base period	TAQ
Amihud	The Amihud's measure of illiquidity, defined as the ratio of the daily absolute return to the dollar trading volume on that day (Amihud, 2002).	CRSP
Big Neg Surp	One, if a 24-hour post-announcement return is negative and below the median of all of the negative earnings announcements, and zero otherwise	TAQ
Big Pos Surp	One, if a 24-hour post-announcement return is positive and above the median of all of the positive earnings announcements, and zero otherwise	TAQ
Earn Surp	The absolute value of a 24-hour post-announcement return	TAQ
EffSpr	The effective relative spread, calculated as twice the absolute difference between the transaction price and the midpoint price, scaled by the midpoint price ($EffSpr_t = 2\left\|P_t - Q_t\right\|/Q_t$). Observations with $EffSpr > 0.5$ are set to missing values	TAQ
Event$_i$, $i \epsilon [-2; +2]$	One for observations on the event day i, where i is calculated as *Current Day - Announcement Day*	I/B/E/S
Illiquid (Illiq)	One, if the relative spread of the stock is above the median value of all of the stocks in the sample, and zero otherwise	TAQ
ISO	One, if an order is marked as ISO, and zero otherwise	TAQ
Leverage	The market leverage, defined as the ratio of the total liabilities to the sum of the total liabilities and the market capitalization of the company	Compustat

Variable	Description	Source
Liquid (Liq)	One, if the relative spread of the stock is below the median value of all of the stocks in the sample, and zero otherwise	TAQ
LnMCap	The natural logarithm of market capitalization	CRSP
MCap	The market value of equity (in million $)	CRSP
Nasdaq	One, if the stock is listed on Nasdaq, and zero otherwise	TAQ
Neg Surp	One, if a 24-hour post-announcement return is negative, and zero otherwise	TAQ
Pos Surp	One, if a 24-hour post-announcement return is positive, and zero otherwise	TAQ
Post-Reg NMS, ($Post\ Reg$)	One, if an announcement happens after the final implementation of the Regulation NMS (October 2007), and zero otherwise	
Pre-Reg NMS	One, if an announcement happens before the final implementation of the Regulation NMS (October 2007), and zero otherwise	
Prc	Stock price (in $)	CRSP
PrcImp	The measure of the five-minute price impact of a trade, defined as $PrcImp_t = 2\left\|Q_{t+5} - Q_t\right\| / (Q_t * w_t)$, where Q_{t+5} is the midpoint price of the stock after five minutes and w_t is the size of the trade	TAQ
Proportion of ISO trades, %Trades	The ratio of the number of intermarket sweep orders to the total number of orders executed within a given time interval	TAQ
Proportion of ISO volume, %ISOvol	The ratio of the volume that is executed with intermarket sweep orders to the total volume traded within a given time interval	TAQ
Proportion of ISO purchases, %Purchases	The ratio of the number of purchase transactions that are executed with intermarket sweep orders to the total number of purchase transactions within a given time interval	TAQ
Proportion of ISO buy volume, $\%ISOBuyVol$	The ratio of the volume of purchase transactions that are executed with intermarket sweep orders to the total volume of purchase transactions within a given time interval	TAQ

Variable	Description	Source
Proportion of ISO sales, %Sales	The ratio of the number of sale transactions that are executed with intermarket sweep orders to the total number of sale transactions within a given time interval	TAQ
Proportion of ISO sell volume, %ISOSellVol	The ratio of the volume of sale transactions that are executed with intermarket sweep orders to the total volume of sale transactions within a given time interval	TAQ
RelSpr	Intraday relative spread, defined as the difference between the ask and the bid, scaled by their average; observations with *RelSpr>0.5* are set to missing values.	TAQ
RelSpr (daily)	Daily relative spread, defined as the difference between the closing ask and the closing bid, scaled by their average; observations with *RelSpr (daily)>0.5* are set to missing values.	CRSP
ROA	Return on assets, defined as the ratio of the operating income after depreciation to the average total assets of the current year and the previous year.	Compustat
Size	Size of a transaction (in shares)	TAQ
TA_i	ith tercile of trading aggressiveness (TA1 - the lowest tercile of trading aggressiveness and TA3 - the highest tercile of trading aggressiveness)	Own calculations
Total Assets	Total assets (in million \$)	Compustat
Total Liabilities	Total liabilities (in million \$)	Compustat
Turnover	The average daily traded volume divided by the number of shares outstanding	CRSP
VIX	Chicago Board Options Exchange Market Volatility Index, a measure of the implied volatility of S&P 500 index options that represents the market's expectation of the stock market volatility over the next 30 day period	Chicago Board Options Exchange
Volatility	The annualized standard deviation of daily stock returns over the calendar month	CRSP
Volume	The total volume traded within a 10-minute interval (in shares)	TAQ

Figure 3: **The Changes in the Proportion of ISO volume on the Announcement Days.** This figure displays the mean percentage deviations in the proportion of ISO volume throughout the announcement days. The deviations from the bootstrapped means are measured in 15-minute intervals relative to the 15-minute interval with an earnings announcement release (interval 0). The dashed line shows the 1% significance level for the mean percentage change in the proportion of ISO volume, which is equal to 3.8%.

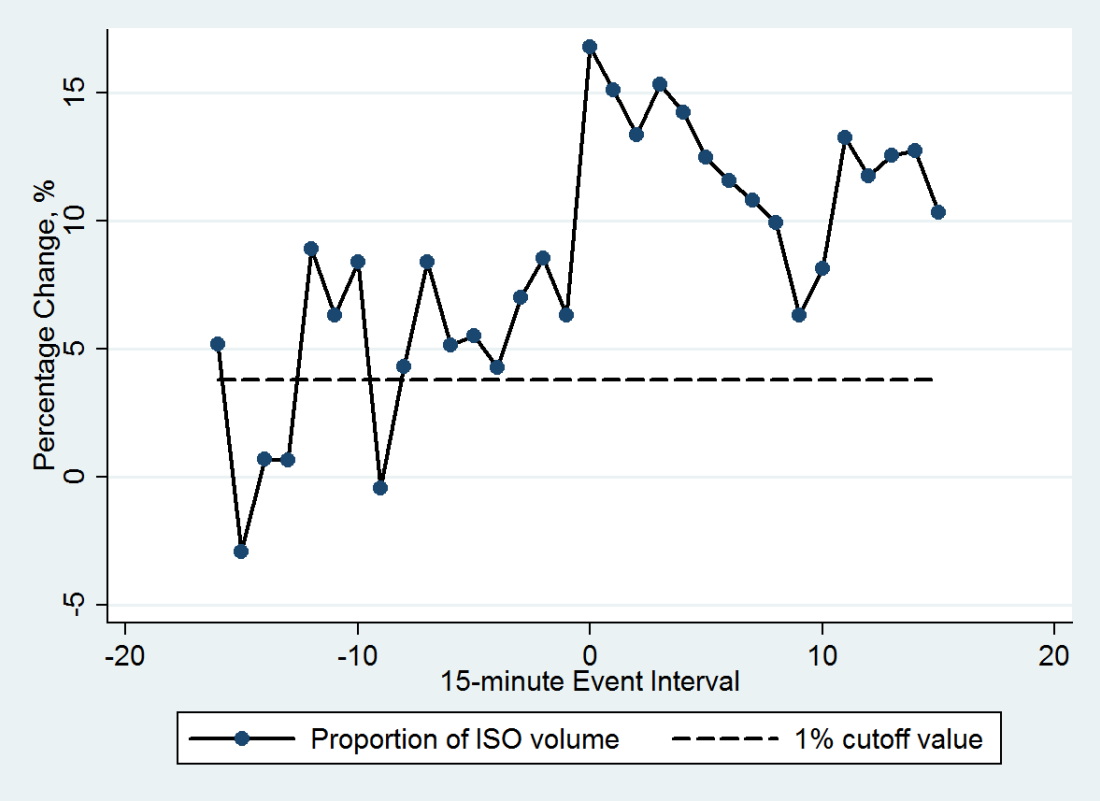
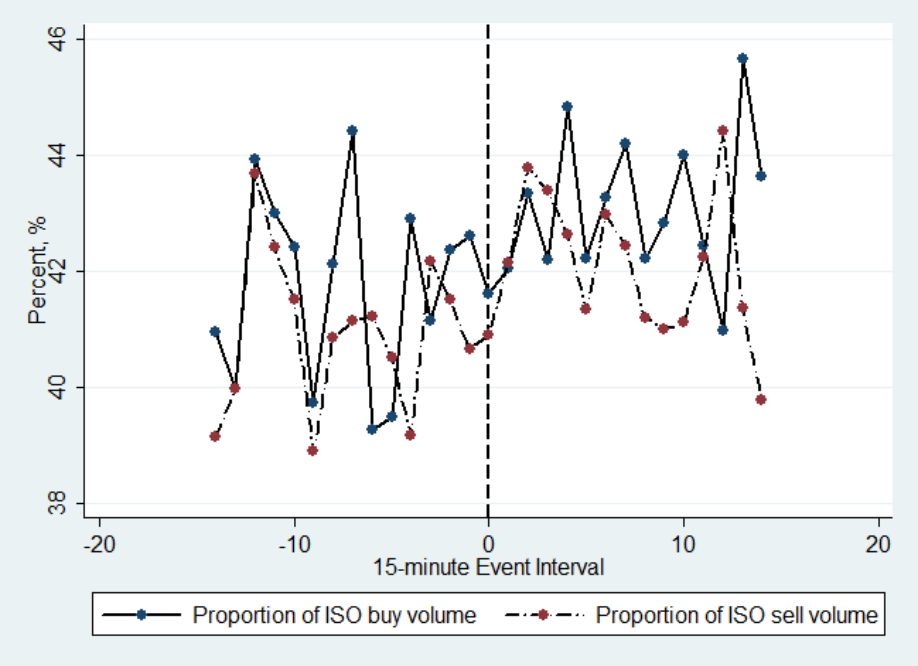


Figure 4: **The Trading Imbalances in ISO volume on the Announcement Days.** This figure displays the mean proportion of ISO buy volume, defined as *ISO buy volume/Total buy volume*, and the mean proportion of ISO sell volume, defined as *ISO sell volume/Total sell volume*, throughout the announcement days. Both proportions are measured in 15-minute intervals relative to the 15-minute interval with an earnings announcement release (interval 0). The dashed line marks the event interval.

A. Positive Earnings Surprises



B. Negative Earnings Surprises

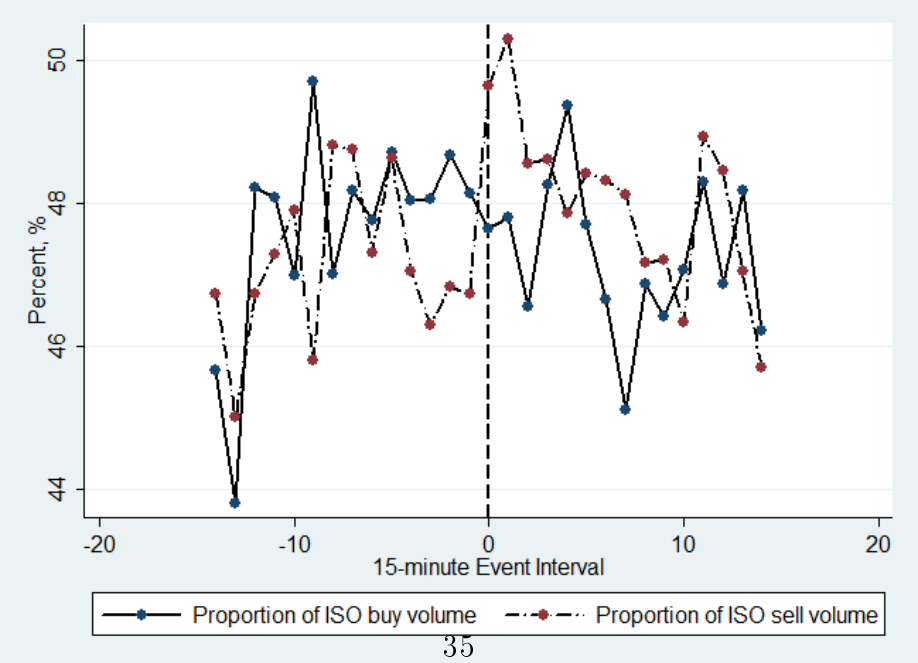
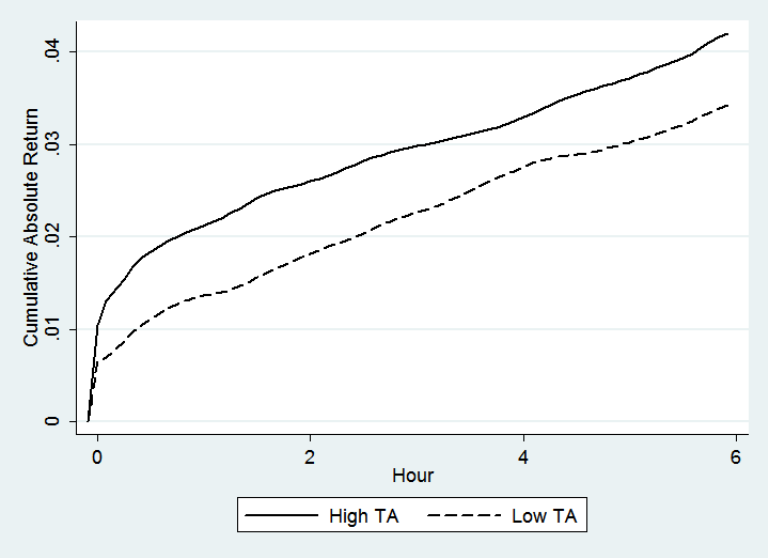


Figure 5: **Development of the Cumulative Intraday Returns and Abnormal Volatility over Time.** Panel A of this figure depicts the development of the cumulative five-minute absolute returns within the first six hours since an earnings announcement release (interval 0). I aggregate positive and negative earnings surprises, and multiply all of the returns for negative earnings surprises by -1. The solid line represents the subsample of the stocks with the above median increases in trading aggressiveness on the announcement day. The dashed line represents the subsample of the stocks with the below median increases in trading aggressiveness on the announcement day. Panel B presents the percentage increases in the realized volatility on the announcement days from its base level, calculated as the mean realized volatility over the same five-minute interval on the non-announcement days [-40;-3]. The realized volatility within each five-minute interval is calculated as the standard deviation of the sum of the squared one-minute closing midpoint returns.

A. Cumulative intraday post-announcement returns



B. Abnormal post-announcement volatility

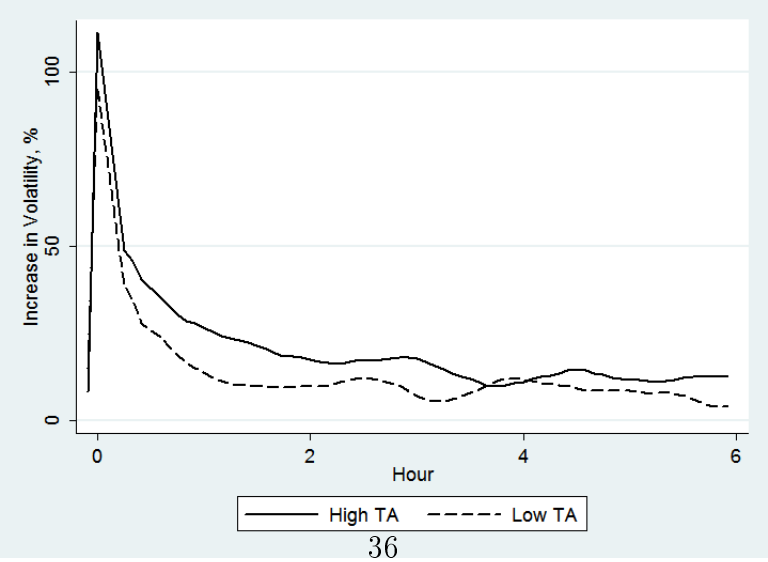


Figure 6: **Adjustment Time and Trading Aggressiveness.** This figure depicts the relationship between the mean length of the price adjustment period and the mean change in the proportion of ISO volume after an information release, separately for the subsamples of liquid and illiquid stocks. The length of the price adjustment period is measured as the number of five-minute time intervals until the realized volatility of one-minute midpoint returns is no longer abnormal.

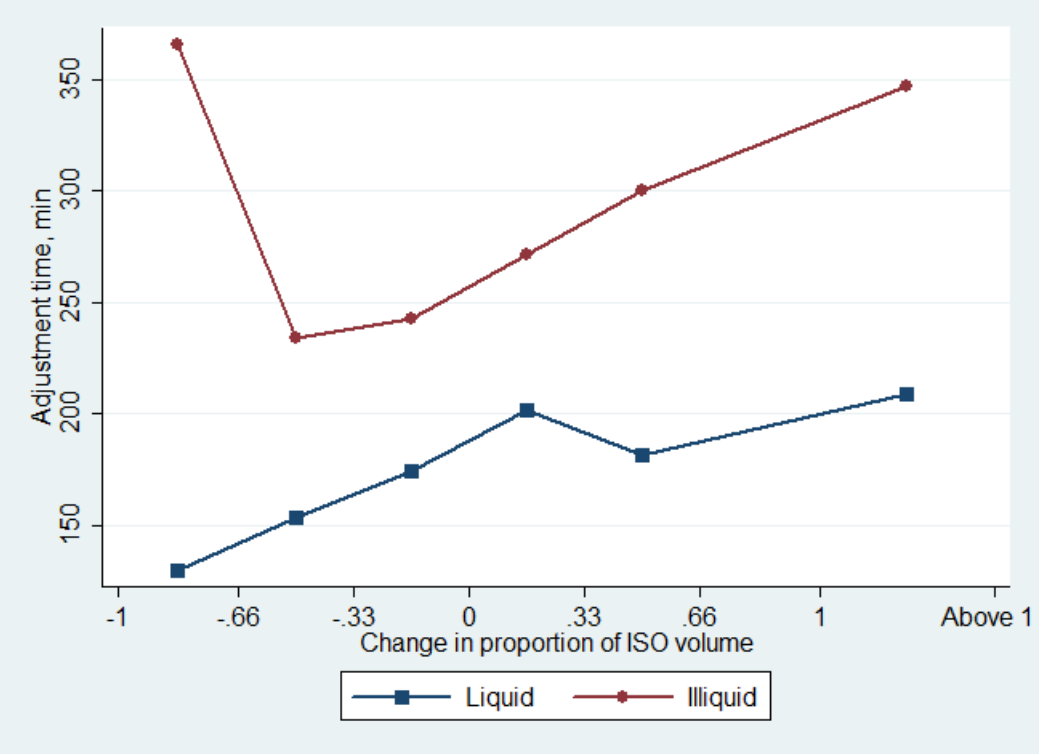


Table 1: **Sample Construction.** This table shows the sample selection of the earnings announcements of US firms that happened within trading hours (from 9:30 a.m. till 16:00 p.m. EST) from 2006 to 2009. The data source for dates and times of the earnings announcements is the Institutional Brokers Estimate System (I/B/E/S) database. I require each firm to exist in the intersection set of I/B/E/S and CRSP.

Criteria	**Announcements**	**Lost obs.**	**Firms**
Initial sample	10,334		3,361
Stock traded on an announcement day	9,687	647	3,273
Intraday transaction data available on TAQ	8,720	967	3,008
Closing price not less than $5	6,126	2,594	2,334
Not more than one announcement per day	6,040	86	2,322
Trading data exists for previous 2 months	5,944	96	2,307
At least one announcement before and one announcement after Reg NMS, out of which:	3,613	2,331	675
- Before Reg NMS	1,818		675
- After Reg NMS	1,795		675

Table 2: **Sample Distributions.** This table displays the distributions of firm characteristics in the final sample (Columns 1 to 3) and the initial sample (Columns 4 to 6). The differences in the means and medians are statistically significant at the 5% level for all of the variables, except the market capitalization, *MCap*, which is statistically significant at the 10% level. See the Appendix for the exact definition of all variables.

	Final			**Initial**		
	N	Mean	50%	N	Mean	50%
	(1)	(2)	(3)	(4)	(5)	(6)
Total Assets (in mln $)	666	8672	686	3300	6220	477
Total Liabilities (in mln $)	666	5990	507	3300	4309	274
MCap (in mln $)	675	2670	256	3361	2254	239
Prc (in $)	675	26	21	3361	20	14
ROA	654	0.07	0.05	3054	-0.01	0.04
Leverage	666	0.54	0.55	3290	0.46	0.41
RelSpr (daily)	675	0.01	0.00	3361	0.01	0.01
Amihud	675	0.95	0.04	3361	1.93	0.06
Volatility	675	0.44	0.41	3361	0.59	0.53
Turnover	675	0.006	0.003	3361	0.007	0.005

Table 3: **The Differences in Characteristics of ISOs and non-ISOs.** Panel A of this table summarizes the differences in trading characteristics between intermarket sweep orders (ISOs) and standard limit orders (non-ISOs) in the base period and after earnings announcement releases. Columns (1) and (2) display the mean of the bootstrapped distribution for ISOs and non-ISOs from the base period, correspondingly. Columns (3) and (4) report the cross-sectional mean of the respective variables starting from an announcement release until the end of the trading day (16:00 p.m. EST). I also report the p-value of the t-test for the null-hypothesis that the difference in means between ISOs and non-ISOs equals zero. * denotes statistical significance at the 10% level, ** - at the 5% level, and *** - at the 1% level. Column (5) displays the difference-in-differences results. For proportions, Column (5) displays the difference between the base period and the event day. Panel B summarizes the differences in trading characteristics between ISOs and non-ISOs after earnings announcement releases for stocks with different liquidity levels. The variables are calculated from the intraday transaction data in the NYSE TAQ database. See the Appendix for the exact definition of all variables.

Panel A: Base Period vs Announcement Day

	Base Period			Event Day			Diff-in-Diff	
	(1) ISO	(2) Non-ISO	Δ_1	(3) ISO	(4) Non-ISO	Δ_2	(5) Δ_2-Δ_1	
%Trades	40.8			45.4			4.6	***
%Volume	37.8			42.4			4.6	***
%Purchases	40.5			44.4			4.0	***
%Sales	41.3			45.5			4.2	***
Size	176	256	***	180	226	***	33	***
EffSpr, %	1.73	1.82	*	1.84	1.86		0.08	
PrcImp, %	1.29	1.20	**	1.47	1.27	***	0.11	**

Panel B: Liquid vs Illiquid on Event Day

	Liquid			Illiquid			Diff-in-Diff	
	(1) ISO	(2) Non-ISO	Δ_1	(3) ISO	(4) Non-ISO	Δ_2	(5) Δ_2-Δ_1	
%Trades	45.0			45.9			0.9	*
%Volume	41.6			43.3			1.8	***
Size	163	200	***	200	257	***	-20	***
EffSpr, %	0.57	0.56		3.43	3.38		0.05	
PrcImp, %	0.64	0.62		2.51	2.04	***	0.45	***

Table 4: **The Regression Analysis of the Effective Spread and the Price Impact.** This table presents the results of panel OLS regressions with the effective relative spread as the dependent variable for Models (1) and (2) and the price impact as the dependent variable for Models (3) and (4). One observation represents a ten-minute trading interval for a stock. All regressions include firm-, year-, daytime- and weekday-fixed effects. See the Appendix for the exact definition of all variables. P-values of the two-tailed t-test with the null-hypothesis of a coefficient equaling zero are reported in form of asterisks to the right of each coefficient. * denotes statistical significance at the 10% level, ** - at the 5% level, and *** - at the 1% level. I also report the number of observations (N) and R^2 for each regression.

	(1) EffSpr	(2) EffSpr	(3) PrcImp	(4) PrcImp
ISO	-0.003	-0.003	0.053 ***	0.016 ***
Illiquid		0.664 ***		0.623 ***
ISO · Illiquid		0.001		0.187 ***
Event_{-2}	0.000	0.003	0.004	0.007
Event_{-1}	0.062 ***	0.064 ***	0.064 ***	0.066 ***
Event	0.049 ***	0.051 ***	0.091 ***	0.097 ***
Event_{+1}	-0.015	-0.011	0.004	0.009
Event_{+2}	-0.034 ***	-0.030 **	-0.000	0.005
ISO · Event_{-2}	0.010	0.010	-0.007	-0.007
ISO · Event_{-1}	-0.012	-0.011	0.002	0.004
ISO · Event	0.020	0.021	0.036 **	0.028
ISO · Event_{+1}	0.001	0.001	0.003	-0.000
ISO · Event_{+2}	-0.003	-0.003	-0.014	-0.015
$1/P$	7.504 ***	6.768 ***	19.374 ***	18.593 ***
Volume	-0.000 ***	-0.000 ***	0.000 ***	0.000 ***
Nasdaq	1.413 ***	1.352 ***	1.197 ***	1.122 ***
N	1489118	1489118	1489118	1489118
R-squared	0.33	0.34	0.31	0.32
Weekday FE	Yes	Yes	Yes	Yes
Daytime FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes

Table 5: **Informativeness of ISO Trades.** This table reports the differences in the means between an increase in the proportion of ISO buy volume and an increase in the proportion of ISO sell volume on the announcement days, separately for the liquid stocks (Panel A) and the illiquid stocks (Panel B). The first column shows the number of hours since an announcement release. Columns (2) and (3) report the results for the positive surprises and the large positive surprises, respectively. Columns (4) and (5) report the corresponding results for the negative surprises. An earnings surprise is measured as a 24-hour stock return since an announcement release, and is classified as large if a 24-hour stock return is above the median for all of the stocks in the sample for the positive earnings surprises and below the median for the negative earnings surprises. The t-statistics of the two-tailed t-test with the null-hypothesis of a difference in means equaling zero are in parentheses below each coefficient. P-values are reported in form of asterisks to the right of each coefficient. * denotes statistical significance at the 10% level, ** - at the 5% level, and *** - at the 1% level.

Panel A: Liquid Stocks

(1) Hour	(2) Pos Surp	(3) Big Pos Surp		(4) Neg Surp	(5) Big Neg Surp
1	0.47%	0.80%		-0.45%	-0.51%
	(0.49)	(0.69)		(-0.45)	(-0.43)
2	0.86%	0.74%		-0.13%	-0.11%
	(1.09)	(0.76)		(-0.17)	(-0.12)
3	0.90%	1.22%		-0.33%	-0.39%
	(1.23)	(1.43)		(-0.44)	(-0.45)
4	0.79%	1.43%	*	-0.13%	-0.17%
	(1.15)	(1.79)		(-0.19)	(-0.20)
5	0.55%	1.45%	*	0.03%	-0.27%
	(0.82)	(1.84)		(0.05)	(-0.34)

Panel B: Illiquid Stocks

(1) Hour	(2) Pos Surp	(3) Big Pos Surp		(4) Neg Surp		(5) Big Neg Surp	
1	-0.73%	1.85%		-6.13%	**	-5.21%	
	(-0.34)	(0.59)		(-2.12)		(-1.43)	
2	0.91%	3.61%		-6.51%	***	-7.11%	**
	(0.44)	(1.26)		(-2.76)		(-2.41)	
3	1.72%	3.76%		-4.95%	**	-7.32%	**
	(0.90)	(1.42)		(-2.21)		(-2.59)	
4	1.27%	3.74%		-6.03%	***	-7.00%	***
	(0.73)	(1.53)		(-2.95)		(-2.75)	
5	0.86%	3.03%		-5.67%	***	-6.86%	***
	(0.50)	(1.28)		(-2.78)		(-2.70)	

Table 6: **The Length of the Price Adjustment Period: Summary Statistics and Univariate Analysis.** Panel A of this table presents the distributions of the length of the price adjustment period (in minutes), separately for the subsamples of liquid and illiquid stocks, in the pre- and the post-Reg NMS periods. See the Appendix for the exact definition of all variables. Columns (3) and (6) report the p-values of the Mann-Whitney test on the equality of medians between the pre- and post-Reg NMS periods for liquid and illiquid stocks, respectively. Panel B displays the mean adjustment time across different terciles of trading aggressiveness (TA1 to TA3) in the post-Reg NMS period. Trading aggressiveness is measured as the change in the proportion of ISO volume that is traded after an announcement release relative to its mean in the base period ($\Delta ISOvol$). The TA1 comprises the stocks with the lowest increases in trading aggressiveness on an announcement day and the TA3 comprises the stocks with the highest increases. The announcements in the pre-Reg NMS period are sorted in "pseudo" - TA terciles that equal the median TA tercile in the post-Reg NMS period. The last two rows report the p-values of the Mann-Whitney test on the equality of the medians across different terciles of trading aggressiveness.

Panel A: Pre-Reg NMS vs Post-Reg NMS

	Liquid			Illiquid		
	Pre-Reg NMS (1)	Post-Reg NMS (2)	MW-test p-value (3)	Pre-Reg NMS (4)	Post-Reg NMS (5)	MW-test p-value (6)
5%	0	0		0	0	
25%	35	35		60	50	
50%	125	100	0.04	178	175	0.97
75%	300	240		480	585	
95%	810	730		955	1020	
Mean	218	188		308	331	
Std	257	234		317	345	

Panel B: Liquidity and Aggressiveness Terciles

	Liquid			Illiquid		
	Pre-Reg NMS (1)	Post-Reg NMS (2)	MW-test p-value (3)	Pre-Reg NMS (4)	Post-Reg NMS (5)	MW-test p-value (6)
TA1	130	105	0.22	235	200	0.78
TA2	115	95	0.14	148	150	0.88
TA3	145	115	0.55	195	225	0.44
TA1-TA3	0.78	0.27		0.31	0.82	
TA2-TA3	0.57	0.22		0.12	0.05	

Table 7: **The Length of the Price Adjustment Period: The Difference-in-Differences Analysis.** This table presents the results of the negative binomial regressions that include observations from the pre- and post-Reg NMS periods. The dependent variable in each model is the length of the adjustment period. Models (1) to (3) report the results for the benchmark definition of abnormal volatility: volatility is abnormal if the realized volatility in a five-minute interval exceeds the 75% cutoff value in the same five-minute interval calculated over days $[-40; -3]$. Models (4) to (6) report the multivariate results for an alternative definition of abnormal volatility: volatility is abnormal if it exceeds the median volatility in the same five-minute period on the non-announcement days. Models (1) and (4) report the results for the total sample, Models (2) and (5) for the positive earnings surprises, and Models (3) and (6) for the negative earnings surprises. See the Appendix for the exact definition of all variables.

	AV: Upper Quartile			AV: Above Median		
	(1) Total	(2) Pos Surp	(3) Neg Surp	(4) Total	(5) Pos Surp	(6) Neg Surp
Adj Time						
Post Reg	-0.20 *	-0.05	-0.35 **	-0.15 *	-0.06	-0.26 **
Illiq	0.35 ***	0.35 ***	0.39 ***	-0.01	-0.01	-0.01
Illiq· Post Reg	-0.07	-0.19	0.01	0.03	-0.01	0.07
Liq· $\lvert\Delta ISOvol\rvert_{\Delta>0}$	-0.01	-0.08	0.08	0.18	0.07	0.31 *
Liq· $\lvert\Delta ISOvol\rvert_{\Delta<0}$	-0.51 *	-0.95 **	0.01	-0.20	-0.27	-0.10
Illiq· $\lvert\Delta ISOvol\rvert_{\Delta>0}$	0.25 ***	0.31 ***	0.18	0.16 ***	0.22 ***	0.08
Illiq· $\lvert\Delta ISOvol\rvert_{\Delta<0}$	0.31 **	0.56 ***	-0.01	0.17 *	0.37 ***	-0.05
Turnover	-9.78 **	-15.84 ***	-5.38	-2.78	-1.58	-3.77
LnMCap	0.00	-0.00	0.01	0.02 *	0.02	0.03
VIX	0.70 ***	0.70 **	0.71 **	0.54 ***	0.47 **	0.62 **
Earn Surp	1.38 ***	1.00	1.95 **	1.62 ***	1.45 ***	1.84 ***
N	3,613	1,826	1,762	3,613	1,826	1,762
P(Chi-Squared)	0.000	0.000	0.000	0.000	0.026	0.005
Weekday FE	Yes	Yes	Yes	Yes	Yes	Yes
Daytime FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Table 8: **The Length of the Price Adjustment Period: Robustness Checks.** This table presents the results of the negative binomial regressions that include observations from the pre- and post-Reg NMS periods. The dependent variable in each model is the length of the adjustment period. Models (1) to (3) use an alternative definition of intraday volatility that is now measured as the realized price range in each five-minute interval. Models (4) to (6) use the benchmark definition of the realized volatility, but differentiate between the samples of liquid and illiquid stocks with the Amihud (2002) illiquidity measure. Models (1) and (4) report the results for the total sample, Models (2) and (5) for the positive earnings surprises, and Models (3) and (6) for the negative earnings surprises. See the Appendix for the exact definition of all variables.

	Price Range			Amihud		
	(1) Total	(2) Pos Surp	(3) Neg Surp	(4) Total	(5) Pos Surp	(6) Neg Surp
Adj time						
Post Reg	-0.20 *	-0.15	-0.21	-0.19	-0.06	-0.28 *
Illiq	0.45 ***	0.46 ***	0.48 ***	0.37 ***	0.39 ***	0.39 ***
Illiq· Post Reg	-0.01	-0.17	0.11	-0.09	-0.16	-0.08
Liq· $\lvert\Delta ISOvol\rvert_{\Delta>0}$	0.10	0.05	0.12	-0.06	-0.08	-0.05
Liq· $\lvert\Delta ISOvol\rvert_{\Delta<0}$	-0.49 *	-0.88 **	-0.15	-0.71 ***	-1.02 ***	-0.35
Illiq· $\lvert\Delta ISOvol\rvert_{\Delta>0}$	0.25 ***	0.37 ***	0.13	0.25 ***	0.29 ***	0.21 *
Illiq· $\lvert\Delta ISOvol\rvert_{\Delta<0}$	0.37 ***	0.55 ***	0.14	0.34 ***	0.56 ***	0.06
Turnover	-12.19 ***	-24.96 ***	-3.64	-9.17 **	-14.48 ***	-5.77
LnMCap	-0.04 **	-0.03	-0.04 *	0.01	0.00	0.01
VIX	0.67 ***	0.74 **	0.61 *	0.70 ***	0.70 **	0.73 **
Earn Surp	1.44 ***	1.33 *	1.79 **	1.38 ***	0.95	1.99 **
N	3,589	1,808	1,756	3,613	1,826	1,762
P(Chi-Squared)	0.000	0.000	0.000	0.000	0.000	0.000
WeekdayFE	Yes	Yes	Yes	Yes	Yes	Yes
DaytimeFE	Yes	Yes	Yes	Yes	Yes	Yes
YearFE	Yes	Yes	Yes	Yes	Yes	Yes