Trading Aggressiveness and Its Implications for Market Efficiency*

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Olga Lebedeva†

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†Warwick Business School, CV4 7AL Coventry, UK. E-mail: olga.lebedeva@wbs.ac.uk. Tel: +44 24765 28956.

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Abstract

This paper investigates the empirical relation between an increase in trading aggressiveness after earnings announcements and speed of price adjustment. Trading aggressiveness allows for quicker price changes within a given time interval. They are beneficial for the initial adjustment stage when aggressive traders agree on the news direction and push price more quickly to its new equilibrium level. However, as traders start to disagree about the precise level of equilibrium price, quick price changes in different directions increase intraday volatility and might slow down adjustment process. This paper shows that the latter effect dominates, and it is especially harmful for illiquid stocks.

JEL classifications: G14, G18, G19

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1 Introduction

This paper analyzes the effect of an increase in 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 potentially better execution price. Such a situation is most likely to arise when investors expect immediate changes in the value of a stock and 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) 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 potentially better price in such moments is costly, because the price 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 about new fundamental value and trade more aggressively in search of a quick profit. However, the implications of large increases in trading aggressiveness on the speed of price adjustment are not straightforward. 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 for the initial stage of price adjustment when everyone agrees on the direction of the news signal. More aggressive orders on this stage push the stock price more quickly towards its new equilibrium value. However, due to their heterogeneous beliefs and different interpretations of the news it takes time for investors to agree on the precise level of equilibrium price. The second "stabilization stage" lasts much longer and is characterized by abnormal trading volume and volatility.[2] Quicker price changes in different

[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. Brooks, Patel and Su (2003) examine the price adjustment process in U.S. equity markets after unanticipated events. They find that the initial price reaction lasts around 20 minutes

directions during this stage may further inflate intraday volatility, which makes price stabilization harder and prolongs the adjustment process.

The positive effect of trading aggressiveness should dominate when the component of the news that everyone agrees on is larger. Normally, traders are more likely to agree when a large amount of information has not been incorporated into price yet, e.g., after negative news about short-sale constrained stocks. Diamond and Verrecchia (1987) show that short-sale constraints prevent traders with negative information to incorporate it into prices before the public announcement release, which explains larger reactions to negative news announcements.[3] In contrast, disagreement between investors is higher after positive earnings surprises, because all relevant information has already been priced in and it is harder to interpret any residual news component. Overall, I expect trading aggressiveness to speed up price adjustment after negative news when traders largely agree and to slow it down after positive news when traders largely disagree. Empirical results of this paper show that, on average, large increases in trading aggressiveness slow down the adjustment process, especially after positive earnings surprises of illiquid stocks. After negative earnings surprises, the adverse effect of trading aggressiveness declines, but I do not find any evidence that trading aggressiveness actually speeds up price adjustment.

I measure trading aggressiveness as a proportion of the total volume that is executed through aggressive orders within a given time interval. To differentiate aggressive orders, I use a special limit order type, called an intermarket sweep order (ISO), introduced as an exemption to the Order Protection Rule of the Regulation National Market System (Reg NMS) in the US to allow institutional investors trade large blocks quickly.[4] Even though it is officially a limit order, an ISO is usually ready for immediate execution against orders already outstanding in the book - in other words, it is a marketable limit order and is used by liquidity demanders. If an order is marked as an ISO, a trading venue has to give this order an immediate execution - even if this execution potentially ignores a better price available elsewhere on the market. With its higher execution speed, an ISO provides an opportunity for traders to take large amounts of liquidity quickly out

after an information release and that prices experience reversals over the following two hours.

[3] Michaely, Thaler, and Womack (1995) empirically confirm larger reaction to negative news on the sample of dividend announcements.

[4] Chakravarty et al (2012) provides an excellent overview of ISO characteristics and their use on the current financial markets.

of the limit order book and thus represents the most aggressive order available on the current US equities markets. Further, submission of ISOs requires simultaneous monitoring of all NMS market centers and is essentially restricted for the use of professional traders.[5]

The major findings of this paper are as follows. Consistent with prior findings of Chakravarty et al (2011a), I show that trading aggressiveness, measured as the proportion of ISO volume significantly increases in post-announcement periods, especially in the sample of less liquid stocks. Further, ISO trades have higher intraday price impacts than non-ISO trades and this difference 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 aggressive orders can move prices of these stocks more easily. ISOs also cause significantly higher post-trade volatility of midpoint returns and larger temporary quote overreaction than non-ISO trades, which is consistent with the evidence of a recent increase in high-frequency quote volatility provided in Hasbrouck (2013).

The main contribution of this paper is the analysis of the link between increases in trading aggressiveness after earnings announcement releases and the speed of price adjustment. Adjustment time is defined as the number of ten-minute intervals from an announcement release until the interval in which the realized variance is no longer abnormal. For identification, I control for differences in the speed of price adjustment in the pre-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 suggest that the effect of trading aggressiveness on price adjustment depends on stock liquidity level. I do not find any significant effects for liquid stocks, since larger depth in limit order books of these stocks makes them less subject to negative effects of aggressive orders. In contrast, large increases in trading aggressiveness significantly slow down adjustment of illiquid stocks: a 100% increase in the proportion of ISO volume increases their adjustment time by around one hour, as compared to the pre-Reg NMS period.

I further test whether disagreement between aggressive traders, measured as the inverse of the difference between an increase in the proportion of ISO buy volume and ISO sell volume, depends

[5]Even though ISOs were originally introduced to allow institutional investors trade their large-sized orders quickly, anecdotal evidence from practitioners suggests that ISOs have now become a common means of trade for market makers and high-frequency traders. Chapter 3 of the book "The Problem of HFT: Collected Writings on High-Frequency Trading and Stock Market Structure Reform" (2013) by Haim Bodek, a managing principal of Decimus Capital Markets LLC, discusses the use of ISOs by high-frequency traders in more detail.

on the direction of the earnings surprise. For liquid stocks, trading aggressiveness on the buy and sell side increases symmetrically in post-announcement periods, irrespective of the news direction. For illiquid stocks, traders disagree and submit aggressive orders in different directions after positive news. However, after negative news the increase in the proportion of ISO sell volume dominates the increase in buy volume by 6%, which signals larger agreement between traders. Consistent with prior expectations, negative effect of trading aggressiveness on adjustment time of illiquid stocks dominates after positive earnings announcements when the disagreement is larger. Importantly, increases in trading aggressiveness do not have positive effects on price adjustment after negative news, even in the subsample of short-sale constrained stocks, for which the agreement between traders should be largest. The overall findings thus suggest that the negative effect of trading aggressiveness during the "stabilization" stage seems to outweigh its potentially positive effect during the initial adjustment stage.

Empirical evidence in this paper shows that trading with aggressive orders destabilizes prices of illiquid stocks in post-earnings announcement periods. Note that earnings announcements are usually scheduled and expected by market participants well in advance. Therefore, they represent one of the most conservative types of information releases. The effect of trading aggressiveness is likely to be even larger during times of unexpected information releases when uncertainty and disagreement between investors reach their highest levels. The regulators should thus consider limiting the use of ISOs during periods with high information sensitivity.

This paper contributes to the on-going debate on the efficiency of financial markets. Specifically, it examines how investor's trading mechanics affects speed of price 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

[6]Lee (1992) examines differences in the clustering of small and large trades around earnings announcements. Other studies examine informativeness of institutional (Ali, Klasa, and Li (2008)) and individual trades (Kaniel, Saar, and Titman (2008), Kaniel et al (2012)) around earnings announcements. 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 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)).

best of my knowledge, only two studies exist that examine the relation between the mechanics of trading and the speed of price adjustment after information releases. Woodruff and Senchack (1988) show that a large number of smaller trades occurs after positive earnings surprises and relatively few but larger trades after negative earnings surprises. Ederington and Lee (1995) examine the short-run dynamics of price adjustment in interest rate and foreign exchange futures markets. They show 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.

This study is also related to the recent literature about high frequency trading (HFT) and its impact on market efficiency. ISOs represent one of potential instruments for high frequency traders to quickly demand liquidity in the market. Theoretical study by Biais, Foucault, and Moinas (2012) shows that HFT who act as liquidity demanders overall increase adverse selection costs of other traders and can even crowd out small uninformed traders from the market. Kirilenko et al (2011) empirically analyze the impact of HFTs during Flash Crash and find that HFTs exacerbated market volatility on that day. This result is consistent with findings in this paper about negative effects of quick liquidity demand on short-term volatility after information releases. However, recent studies by Jovanovic and Menkveld (2012) and Hagströmer and Nordén (2013) show that the majority of HFT actually act as market makers or liquidity suppliers. Liquidity-supplying activities of HFT can even improve price efficiency, as suggested by Bernales and Daoud (2013). Hasbrouck and Saar (2013) and Brogaard, Hendershott, and Riordan (2014) provide empirical evidence that HFTs reduce short-term volatility and contributes positively to price discovery on a day-to-day basis.

The remaining part is organized as follows. Section 2 describes institutional framework and develops main hypotheses of this study. Section 3 provides details of the dataset construction. Section 4 analyzes characteristics of aggressive orders in the base period and around earnings announcements. Section 5 investigates effects of trading aggressiveness on speed of price adjustment and 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 implements partial protection against trade-throughs on US markets. A trade-through occurs when the best available bid or offer quotation is ignored, or in other words, "traded-through". For example, assume there are only two trading venues, A and B. Table 1 shows the bid sides of visible limit order books in two venues.[9] The first column shows the currently quoted bid prices, the second and third columns indicate the number of shares available at each price for venues A and B, respectively. Prior to Reg NMS, a market order sent to exchange A would just walk down the limit order book of A until either the order is completely filled or the limit price of the order is reached. For instance, an order of 4,000 shares would be split into 500 shares executed at \$10.75, additional 2,000 shares at \$10.70 and remaining 1,500 shares at \$10.67. The best bid of \$10.73 at B is then ignored or "traded-through".

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

Price	Shares A	Shares B
\$10.75	500	
\$10.73		500
\$10.70	2,000	600
\$10.67	3,500	

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

[9] For simplicity, I consider all orders to be visible. Adding hidden orders does not change the argument of this paper.

With the new Order Protection Rule, when a new market (or marketable limit) order arrives, the trading venue has to check whether the order (or its portion) would cause a trade-through of better quotes on other venues. Should other venues quote better prices, the order (or its corresponding portion) must be automatically re-routed for execution to other venues. However, the order protection is partial, because it is only limited to the top visible quotes in the book of each venue, referred to as the Best Bid and Offer (BBO). In the previous example, only 500 shares at \$10.75 on A and 500 shares at \$10.73 on B are protected quotes. To comply with the Order Protection Rule, venue A has now to re-route 500 shares for execution at B before executing the remaining part of the order. Such execution would still result in a trade-through of 600 shares available at \$10.70 on B, but this quote is not considered to be "protected" and can therefore be ignored under the current rules.

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 best-priced bid and ask quotes on each trading venue from potential trade-throughs encourages liquidity providers to post limit orders at best prices. Although appealing to retail investors with a long-term investment horizon, the Order Protection Rule is less attractive for short-term and institutional investors: re-routing takes time and the best bid 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) that 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, exactly as in the pre-Reg NMS period. Importantly, there is no re-routing requirement, even if some parts of the order cause trade-throughs of the protected quotes at other venues. However, to still ensure compliance with the principles of the Order Protection Rule, an investor who submits an ISO is responsible for sending additional limit orders, also designated as ISO, to other venues quoting the stock. The size of these additional ISOs should be sufficient to execute against the total number of shares available at protected quotes that are superior to the ISO limit price. Therefore, an ISO represents a series of marketable limit orders sent across all trading venues quoting the stock at the BBO that is superior to the ISO limit price.[10]

To illustrate, suppose that an institutional investor would like to use an ISO to sell 4,000 shares at the limit price of $10.67. To comply with the Order Protection Rule, he has to send two limit orders, marked as ISO, of at least 500 shares each with the limit price of $10.67 simultaneously to both venues. An investor has a choice how to split his total order: he can either send 3,500 shares to A and 500 shares to B or 2,900 to A and 1,100 to B. In the latter case, the split is optimal, because the investor gets better average execution price. Still, some investors might choose to send a larger portion of their order to A because they believe that the speed of execution on A is faster. 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 and the new best price drops to $10.70 in the case of the suboptimal ISO split and to $10.67 in the case of the optimal split.[11]

In the previous example, under the assumption that the limit order book does not change between the time of order submission and its execution, a series of ISOs sent across exchanges will always execute at the average price that is at least as good as that for a standard limit order. So where is the tradeoff between the speed of execution and execution at a better price? In reality, the state of the book might change when the routing decision for ISO has already been taken. Suppose a new bid quote at $10.75 for 1,000 shares appears on another venue C at the time when both an ISO and a non-ISO are already on their way to A. The ISO is executed exactly as before, whereas additional 1,000 shares of the non-ISO are re-routed to C. The average execution price of the non-ISO is overall better in this case. However, this case is most likely to occur during normal trading period when

[10] 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.

[11] Prior to Reg NMS an ISO could be replicated as a series of smartly routed marketable orders. However, the speed of execution was the same for all orders in the market. Even though technological advancements might have increased the absolute speed of order execution post-Reg NMS, the Order Protection Rule "slowed down" the execution of standard market (or marketable limit) orders relative to ISOs, thus generating a relative difference in the speed of execution between ISOs and non-ISOs.

liquidity supply is not scarce and there are no upcoming information releases about the stock. By contrast, as liquidity supply drops around information releases and the fundamental value of the stock is expected to change, there is a higher probability that a better priced quote (in this case: 500 shares at \$10.73) is withdrawn by the time the re-routed order reaches the exchange B. For example, after negative news, an immediate sell with an ISO will result in the overall better average execution price, as compared to the execution price of non-ISO orders. Therefore, in highly volatile markets, traders care more about the immediacy of execution rather than about the execution at the potentially better price.

2.2 Hypothesis Development

Price Impact of an ISO. With their ability to sweep liquidity almost instantly up to a particular price level, ISOs on average produce a higher change in the best bid/ask price *within a given trading interval*, as compared to the standard limit order: *the average price impact of ISO within a given trading interval is higher.* To illustrate this point, assume that if an investor trades one share, then the best 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 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 ISO 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 original ISO 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.*

The price impact of the standard limit order $\sigma \cdot s$ is only realized fully in *t+1* if the depth at the top of the book of the respective exchange is greater than or equal to s. This case is most likely for stocks with high liquidity levels. In all other cases, the order (or its portion) are re-routed to venues with protected quotes and the price impact in *t+1* is only partial, $\sigma \cdot y$, $y < s$. For this reason, the price impact of a standard limit order within t+1 is on average lower, as compared to the price impact of a similar aggressive order.

Consider the previous numerical example with venues A and B. For clarity of exposition, I assume that the investor has chosen a suboptimal split for an ISO such that the average execution price is the same for ISO and non-ISO. Table 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.

Table 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	3,500	\$10.75	\$10.73	\$0.02	4,000	\$10.75	\$10.70	\$0.05
2	Re-routing to B								
3	Execution on B	500	\$10.73	\$10.70	\$0.03				
	Total	4,000			\$0.05	4,000			\$0.05

Note that in t=1 the price impact of the standard order equals only \$0.02, whereas the price impact of the aggressive order, \$0.05, is fully realized, because the total size of the order is immediately executed at both venues. If the limit order book did not change over time, the cumulative price impact of both orders would be the same after t=3. However, with the dynamic limit order book, the full price impact of the standard limit order might never get realized. For example, if additional 500 shares are posted at \$10.75 on B, the re-routed portion of the non-ISO will execute against the new quote and the best price will remain at \$10.73.[12]

Liquid versus illiquid stocks. 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, I expect *the difference in price impact within a given trading interval* between an ISO and a standard order to be higher for less liquid stocks. The effect

[12]The argument does not change if an investor splits an ISO optimally to get the best possible execution price. In this case, the price impact of an ISO is even larger since the best price drops immediately to \$10.67.

of an aggressive order on the price of an illiquid stock is larger, because a larger number of shares is executed within a given trading interval and, additionally, the price changes by a larger amount per each share traded. Basically, the effect of a thinner book for illiquid stocks is additionally multiplied with the effect of faster trading with aggressive orders: an aggressive order goes faster through a thinner limit order book. Therefore, I expect the effects of aggressive trading on the speed of price adjustment to be particularly important for less liquid stocks.

Speed of Price Adjustment. After an information release, the expected fundamental value of a stock changes and the price has to adjust to the new information. Arguably, every news consists of two components: the first component is related to the direction of the news, whereas the second component is related to the precision of the news signal. Usually, everyone agrees whether the news is positive or negative, so there is no or little disagreement about the first component. The question is just how good the good news or how bad the bad news is. Therefore, investors mostly disagree on the precise level of the new fundamental value, either because they differ in rates of their information processing or because they interpret new information differently.[13]

Because of heterogeneity in investor beliefs, price adjustment is not immediate, as suggested by the Efficient Market Hypothesis of Fama (1965), but rather comprises two stages. In the initial stage, investors trade in the direction of the news. In this stage, price quickly moves to a range of values that everyone agrees upon. In the second stage, investors start to disagree about the precise level of the new fundamental value within a range. Thus, they trade in different directions, reflecting their individual interpretations of the news. The second "stabilization" stage usually lasts for several hours and is characterized by abnormal trading volume and volatility.[14]

The example from the previous section shows that an ISO has on average a higher price impact within a given trading interval, as compared to the standard limit order. Therefore, a higher proportion of aggressive orders in the order flow subsequent to an announcement release enables

[13]Recent theoretical studies incorporate heterogeneity of investor beliefs in their models of stock trading by assuming that either investors have differences in interpreting an announcement (Holthausen and Verrecchia (1990), Harris and Raviv (1993), Kandel and Pearson (1995), and Cao and Ou-Yang (2009)) or that they are differentially informed (Kim and Verrecchia (1991), He and Wang (1995) and Hong and Stein (1999)).

[14]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. 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.

quicker price movements within short time intervals. Quicker price movements are beneficial for the initial stage of price adjustment when the majority of traders agrees on the new equilibrium value of a stock. Trading with ISOs in the direction of the news pushes the stock price more quickly towards its new equilibrium value and accelerates price adjustment. The larger the component of news everyone agrees on the more positive this effect is.

When do such situations happen? For everyone to agree on the large part of news, either the processing capacity of traders has to increase, or the news should be relatively easy to interpret. Theoretical papers by Dugast (2013) and Peng (2005) address the former argument and show that a higher intensity of financial markets monitoring and a larger information capacity allocation to a stock makes price adjustment quicker. For the news to be easy to interpret, the large part of it should not have been incorporated into prices yet. In their seminal paper, Diamond and Verrecchia (1987) show that short-sales constraints prevent negative news to be fully incorporated into prices prior to an announcement. Upon the public information release, investors therefore agree on a larger component of negative news and the immediate price reaction is larger in this case.

The initial stage of price adjustment is, however, rather short and normally lasts not more than a couple of minutes. By contrast, the second "disagreement" stage, when investors update their beliefs from the market price and trade accordingly, is much longer. Quick trading with aggressive orders in different directions can further inflate short-term intraday volatility that is already high in this stage.[15] Thus, quicker price movements enabled by increased trading aggressiveness can also slow down the adjustment process, since they make it harder for short-term volatility to drop down to its normal level and for the price to stabilize.

I expect the negative effect of ISOs on the speed of price adjustment to outweigh when the disagreement between investors is larger after an announcement release. According to Diamond and Verrecchia (1987), disagreement should be higher after positive news, because all relevant information has already been priced in and any residual news component is harder to interpret. Kothari, Shu, and Wysocki (2009) provide empirical evidence that a greater fraction of news is incorporated in stock prices before positive announcements. However, they interpret this finding as

[15]In their model,Cao and Ou-Yang (2009) show that trading volume and absolute price changes are positively serially correlated after an announcement release and increase with the dispersion of beliefs among investors.

the evidence that managers leak positive news to the market but prefer to withhold negative news. Miller (1977) shows that prices for short-sale constrained stocks might even overshoot if there are large differences in investors' opinion, since all shares end up being held by investors with the highest evaluations of the stock.

Overall, the arguments above suggest that the effect of aggressive trading on price adjustment is ambiguous and crucially depends on heterogeneity of investor beliefs after an announcement release. In the following sections, I will test the effects of aggressive trading separately for positive and negative announcement releases. I expect aggressive trading to speed up price adjustment after negative releases since a large component of news has not been incorporated in prices yet. For positive news, I expect aggressive trading combined with larger divergence in investor opinions to make the adjustment process slower. Both effects should be more pronounced for illiquid stocks since additional price impact of aggressive orders is overall larger for these 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).[16] 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 3 provides details of the sample construction.

[Insert Table 3 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. I further eliminate very illiquid stocks for which the closing price is less than $5 at the beginning of the base period. Excluding days

[16] I use earnings announcements from the pre-Reg NMS period to form the control group of stocks.

with multiple announcements and announcements with less than 40 days of trading data previously available leaves 5,944 announcements by 2,307 firms.[17] 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 4 summarizes the main firm characteristics in the final sample and the initial sample. All variable definitions are in the Appendix A.

[Insert Table 4 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 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.[18]

[17] 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].

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

3.2 Intraday Transaction and Quote Data

The source for the intraday transaction data is the NYSE Trade and Quote database (TAQ). ISOs are marked with the code "F" in the condition field of the TAQ trade database. Appendix B provides further information on data filtering and merging trade and quote databases. I extract number of trades and trading volume separately for ISO and non-ISO trades and calculate following liquidity and volatility measures:

Liquidity measures. The *quoted relative spread* is defined as the difference between the prevailing NBBO ask and the NBBO bid at the time of the trade, scaled by the midpoint price ($RelSpr_t = (A_t - B_t)/Q_t$). I set observations with $RelSpr > 0.5$ to missing values. *Depth* is calculated as the sum of shares available at the NBBO bid and NBBO ask (in thousands).

The *effective relative spread* of each transaction is calculated as twice the absolute difference between the transaction price and the prevailing NBBO 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 *s seconds* is defined as $PrcImp_{t,s} = 2\left|Q_{t+s} - Q_t\right|/Q_t$ where Q_{t+s} represents the midpoint price for a stock after *s seconds*.[19]

Volatility measures. Two most commonly used measures of intraday volatility are realized variance and realized price range. Andersen et al (2001) show that the *realized variance*, $RealVar_s$, calculated as the sum of the squared high-frequency midpoint returns within a given time interval s, represents the most unbiased and efficient estimator of daily as well as intraday volatility ($RealVar_s = \sum_{t=1}^{s}(log\,Q_t - log\,Q_{t-1})^2$). As illustrated by Martens and van Dijk (2007), the realized variance is also robust in the presence of infrequent trading and non-trading intervals. Further, Martens and van Dijk (2007) propose the realized *price range* measure that accounts for the price level of the stock and is defined as $PrcRng_s = \frac{(log\,H_s - log\,L_s)^2}{4\,log\,2}$, where H_s is the maximum midpoint price within a given time interval s and L_s is the corresponding minimum midpoint price.

To investigate quote reaction after aggressive trades in more detail, I also calculate mean absolute percentage quote overshooting after purchases, $Pos\,Overshoot_s$ and after sales, $Neg\,Overshoot_s$. The intuition behind these measures is to see whether there is any temporary positive quote over-

[19] Note that this measure is equivalent to the commonly used five-minute price impact measure for $s = 300$.

reaction after buys and negative after sells, relative to the closing NBBO of the given time interval s. For example, to calculate mean percentage overshooting after a purchase for a time interval of s seconds, $Pos\,Overshoot_s$, I proceed as follows:

1) Find the midpoint price of closing NBBO in s seconds after the trade, C_{t+s} .

2) If $C_{t+s} > C_t$, calculate percentage overshooting for each quote midpoint Q_n, $n = 1, ..., N$ that belongs to the interval (t; t+s) as $Overshoot_n = max[log(Q_n) - log(C_{t+s}); 0]$. If the quote midpoint is above the closing NBBO in s seconds, $log(Q_n) - log(C_{t+s})$ shows the percentage by which it is overshooting the NBBO. If the quote is below the NBBO, I set $Overshoot_n$ to zero.

3) Calculate mean percentage quote overshooting as $Pos\,Overshoot_s = \frac{1}{N} \overset{[}{n}= 1]N\sum Overshoot_n$. Normally, after a purchase, the midpoint price should go temporarily up. If it went down instead, such that $C_{t+s} < C_t$, I set $Pos\,Overshoot_s = 0$.

The procedure is similar for mean percentage overshooting after sales, $Neg\,Overshoot_s$. In step 2, $Overshoot_n = min[abs(log(Q_n) - log(C_{t+s})); 0]$ if $C_{t+s} < C_t$, where $abs(log(Q_n) - log(C_{t+s}))$ shows absolute percentage by which the quote is below the closing NBBO. If $C_{t+s} > C_t$ after a sale, I set $Neg\,Overshoot_s = 0$.

Transaction-by-transaction data for all measures is collapsed over 10-minute intervals and covers announcement days for all stocks in the final sample as well as 40 trading days before the announcement. The base period consists of 39 trading days preceding an announcement day, starting on day -40 and ending on day -2.

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, $\%ISOVol$). 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.[20] In the remainder of the paper I use the terms "trading aggressiveness", "trading with aggressive orders" or "trading with ISOs" interchangeably.

The mean proportion of ISO volume in my sample is 36.16%. However, the variation is quite significant with 20.58% of the volume traded with ISOs for firms in the lowest decile and 50.13% in the highest decile (not tabulated).

Trading characteristics of aggressive orders. Panel A of Table 5 summarizes differences in trading aggressiveness in the base period and on earnings announcement dates.

[Insert Table 5 approximately here]

Column (1) displays the mean of the bootstrapped distribution for ISOs in the base period, consisting of days [-40;-2] preceding the announcement date.[21] Column (2) reports the cross-sectional mean of the respective variables on an announcement day. Columns (3)-(4) and (5)-(6) report the same statistics separately for subsamples of liquid and illiquid stocks. A stock is defined as illiquid if its relative spread in the base period is above the median value of all stocks in the sample. P-values of differences between means in the base and event periods are based on percentiles of the bootstrapped distribution.

Both, proportion of trades, executed with aggressive orders, $\%ISOTrades$, and proportion of ISO volume, $\%ISOVol$, increase significantly by around 4% on an earnings announcement day. Aggressive orders are used more commonly for liquid stocks in the base period, which might be explained by the fact that liquid stocks have on average higher institutional ownership. Remember that ISOs were primarily introduced as an exemption for institutional investors to enable them trade large blocks quickly. However, a percentage increase in trading aggressiveness on an announcement day is slightly higher for illiquid stocks, 4.67%, as compared to 4.09% for liquid stocks.

Aggressive trading constitutes 36.96% of total purchase volume and 35.69% of total sales volume

[20] The proportion of the total number of trades executed with ISOs is highly correlated with the proportion of ISO volume (correlation coefficient of 91%).

[21] Since the base period is rather short (39 days) and proportions of the number of trades and of their volume might not be normally distributed, I bootstrap their means from empirical distribution. Specifically, I draw with replacement one daily observation from the base period 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.

in the base period. These proportions are almost symmetrical for liquid stocks, but the proportion of ISO purchase volume dominates the proportion of ISO sales volume by more than 2% in the sample of less liquid stocks in the base period. Further, an increase in the proportion of ISO sales volume for illiquid stocks on an announcement day constitutes 5.76%, as compared to 3.09% for purchases. This finding suggests that trading aggressiveness for illiquid stocks increases to a larger extent after negative earnings surprises, when all investors largely agree on the interpretation of the news and rush to sell the stock. A more detailed analysis of this issue follows in the following section.

The reasons for an increase in trading aggressiveness on an announcement day are twofold. First, investors have different rates of information processing. Those investors who are able to process new information more quickly will try to exploit their advantage. Second, investors who would like to trade on their heterogeneous beliefs might choose to trade more aggressively because of the decreasing liquidity supply around earnings announcements. Chakravarty et al (2011a) provide empirical evidence in support of this explanation.

Panel B of Table 5 summarizes differences in characteristics between ISOs and standard limit orders (non-ISOs). The average size of a single ISO in the base period is 176 shares, which is significantly lower than 209 shares for a non-ISO order. The TAQ database does not record a cumulative size for an ISO sent simultaneously across several exchanges, but rather the size of each individual order sent and executed on a particular stock exchange. If I aggregate the size of all orders submitted in the same second and in the same direction, separately for ISOs and non-ISOs then the differences in sizes are not significant any longer. Since all further analysis is based on the proportion of ISO volume, trade aggregation does not play any further role in this paper.

By definition, an aggressive order trades off speed of execution against the execution at the best possible price. Therefore, we should expect ISOs to be executed at less favorable prices than non-ISO orders. However, statistics on volume-weighted average prices of sell orders show that this is not always the case. Specifically, ISO sell orders are on average executed at higher prices than non-ISO sell orders, and the difference between the two is significant at the 5% level on announcement dates. Further, the differences between effective relative spreads of ISOs and non-ISOs are neither significant in the base period nor on announcement dates.[22] These findings suggest that ISOs are not necessarily always executed at inferior prices and can get even better execution prices than non-ISOs, especially after negative news releases. The prevailing NBBO relative spread at the time of order execution is significantly lower for ISOs, which provides partial evidence that aggressive traders engage in liquidity timing both in the base period and on an announcement date.

Determinants of intraday ISO trading volume. The previous analysis shows that ISOs constitute a considerable proportion of trading volume and this proportion increases significantly on dates of earnings announcement releases. The next step is to examine the intraday determinants of ISO trading volume, both in the base period and around earnings announcement releases. Chakravarty et al (2012) conduct the intraday analysis of ISO use during normal trading days. I largely follow their analysis for the base period and estimate panel data OLS regressions with the proportion of ISO volume ($\%ISOvol$) as the dependent variable. One observation represents a ten-minute trading interval for a stock. The vector of explanatory variables consists of 3 lags of the dependent variable; $RelSpr$, the average prevailing NBBO relative spread at the time of ISO execution; $RealVar_{-5sec}$, the NBBO quote midpoint realized variance in five seconds prior to ISO execution, averaged for all ISO trades within each 10-minute interval t; $Depth$, the average sum of shares available at the best bid and the best ask; and $N\ Exch$, the average number of exchanges that offer depth at NBBO (either on the ask or on the bid side). Following Chakravarty et al (2012), I also include year-fixed effects and intraday dummies for each half-hour of the trading day, excluding the middle period 8 as the base case.

[Insert Table 6 approximately here]

Model (1) of Table 6 presents the results for the base period, which are overall consistent with findings of Chakravarty et al (2012). The proportion of ISO volume is positively serially correlated and it increases as prevailing NBBO relative spreads drop, again suggesting that aggressive traders

[22] If ISOs were on average executed at inferior prices, their distance to the midpoint price would be larger and effective relative spreads higher than for non-ISO orders. In contrast to my findings, Chakravarty et al (2012) find significantly higher effective spreads for ISOs in their sample. However, consistent with their findings, I also find higher effective spreads for ISOs in sample of less liquid stocks.

time liquidity of the stock in the base period. Trading aggressiveness increases with lower depth, lower number of exchanges that quote NBBO and higher realized variance of midpoint returns in the previous 5 seconds. These results continue to hold and are even more pronounced on announcement dates (Model (2)), except for *Depth*, which is no longer significant. For models (2)-(4), I additionally include the degree of earnings surprise, $EarnSurp$, measured as the absolute value of the 24-hour post-announcement return, as a control variable. However, it is not statistically significant. Importantly, when I split the observations on announcement dates into pre-announcement period (Model (3)) and post-announcement period (Model (4)), the coefficient on $RelSpr$ loses its significance in the post-announcement period. Even though traders continue to time liquidity with their aggressive trades in the pre-announcement period, they seem to no longer care about it as soon as the announcement is released.

To investigate this issue further, I examine changes in the use of aggressive orders at the intraday level. Figure 1 displays mean percentage deviations in the proportion of ISO volume throughout the announcement day, separately for liquid and illiquid stocks. The deviations from the bootstrapped cross-sectional means are measured in 10-minute intervals relative to the 10-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 for liquid stocks, which is equal to 2.36%. The dash-dotted line shows the corresponding 1% cutoff value for illiquid stocks equal to 5.26%.

[Insert Figure 1 approximately here]

For liquid stocks, the proportion of ISO volume significantly deviates from its mean in the base period in 2 hours before the announcement release and experiences a jump of 13.87% in the first 30 minutes after the information release. Afterward, it decreases, but never drops below the 1% cutoff value within 2 hours of the announcement release. Trading aggressiveness for illiquid stocks is not abnormal during pre-announcement hours, but jumps by more than 20% in the first 30 minutes after the release and continues to deviate by approximately the same percentage as for liquid stocks.

Overall, findings from the previous analysis suggest that there is an important difference between the use of ISO orders in normal trading periods and around earnings announcement releases. In the periods of normal trading ISO orders are mostly used for liquid stocks to trade large blocks quickly, which exactly justifies their introduction to equity markets. However, after earnings announcement releases, traders increase their trading aggressiveness especially for illiquid stocks, thereby extracting all available liquidity in stocks with already scarce liquidity supply.

Intraday analysis of price impact and volatility. One of main assumptions in Section 2 of the paper is that an ISO trade split across several exchanges has a higher price impact within a given time interval, as compared to a non-ISO trade. I cannot test this assumption directly, since I cannot trace back original ISO orders in TAQ database. However, since execution of an ISO trade happens simultaneously across different exchanges, it is reasonable to assume that the price impact of an individual ISO trade in the consolidated order book is a good measure of the price impact of the cumulative ISO order. The results from the bootstrap analysis in Table 7 confirm that ISO trades have an overall higher price impact within a given trading interval than non-ISO trades, both for liquid stocks (Panel A) and illiquid stocks (Panel B). Importantly, this result holds for price impact measured over different time intervals: starting from one second after the trade and up to one minute. I also measure pseudo-price impact (as the change in the NBBO midpoint price) five seconds before the trade and do not find any significant differences between ISO and non-ISO trades. As expected, the difference in price impact between ISO and non-ISO trades is significantly larger at 1% for illiquid stocks (the difference-in-differences result is not tabulated).

[Insert Table 7 approximately here]

In addition to price impact, Table 7 also reports differences in post-trade volatility measures between ISO and non-ISO trades. As with intraday price impact, realized variance, price range and mean percentage quote overshooting after purchases ($Pos\,Overshoot$) and sales ($Neg\,Overshoot$) is significantly higher for ISOs for time intervals of one second and five seconds for all stocks. The impact of ISOs on intraday volatility of illiquid stocks continues to hold even after one minute after the trade, but loses its significance in the sample of liquid stocks. Again, volatility measured five seconds before the trade does not differ between ISO and non-ISO trades.

Table 8 additionally investigates differences between ISOs and non-ISOs in a multivariate setup. The dependent variables are the intraday price impact and post-trade volatility, measured five seconds after each trade and subsequently averaged over ten-minute intervals.[23] All models are panel OLS regressions with daytime- and year-fixed effects. The main variables of interest are *ISO,* which equals one for ISO trades, and zero otherwise, and the interaction of ISO with the relative spread, $ISO \cdot RelSpr$. In addition, I control for lags of dependent variables, the overall liquidity level of a stock ($RelSpr$), the inverse of the mean stock price in a ten-minute period ($1/P$); the total volume executed within a 10-minute trading interval ($Volume$); and the overall level of volatility in the market, proxied by the market volatility index (VIX).

[Insert Table 8 approximately here]

In line with previous results from Table7, the intraday price impact and post-trade volatility is significantly higher for ISO trades and even more so, when stocks are less liquid. After controlling for other control variables, the additional intraday price impact of an aggressive order rises by 0.027% for 1% increase in the relative spread, which is statistically and economically significant (e.g., 0.7 cent larger midpoint price increase per 5 seconds for an average stock in my sample with a price of $26 and a relative spread of 1%). ISOs also produce 0.012% higher realized variance, 0.014% higher percentage overshooting after purchases and 0.007% after sales per 1% increase in the relative spread. Results from Tables 7 and 8 suggest that ISO trades cause significantly higher price impact, short-term quote volatility and quote overreaction than non-ISO trades.

5 Trading Aggressiveness and the Speed of Price Adjustment

Recall from Section 2 that an increase in trading aggressiveness can accelerate initial price reaction, by pushing price more quickly towards its new equilibrium value. However, if the majority of aggressive traders disagrees on the precise level of the new fundamental value, quick trading with ISOs in different directions can also prolong the subsequent stabilization stage and unnecessarily increase post-announcement intraday volatility. Figure 2 provides evidence in support of both statements. Panel A shows that stocks with higher increases in trading aggressiveness on announcement days

[23]Results are robust for different lengths of time interval after the trade and are available upon request.

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 volatility, 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.

Disagreement between aggressive traders after earnings announcements. According to Diamond and Verrecchia (1987), I expect aggressive traders to agree on a larger component of the news after negative earnings surprises. I test the degree of disagreement between aggressive traders by computing the differences between an increase in ISO buy volume and in ISO sell volume, separately after positive and negative earnings surprises:

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

where $\Delta_{Buy} = \%BuyVolume_{Event} - \%BuyVolume_{Base}$, and $\triangle_{Sell}$ is calculated in a similar way. The mean proportions of ISO buy and sell volume in the base period are based on the bootstrap distribution for each stock. A positive (negative) earnings surprise is defined by the direction of the 24-hour post-announcement return. If aggressive traders agree to a large extent, then the proportion of ISO volume should increase more in the direction of the earnings surprise - $\triangle$ should be positive after positive news and negative after negative news.

[Insert Table 9 approximately here]

Columns (1) and (2) of Table 9 present results after positive earnings surprises for liquid and illiquid stocks, respectively. On average, investors increase their trading aggressiveness in the correct direction: they increase the proportion of ISO buy volume by a larger amount than the proportion of ISO sell volume ($\Delta > 0$). However, the difference between the two is not significant, suggesting that aggressive traders largely disagree in their views after positive news and trade in different directions.

Interestingly, the results differ between liquid and illiquid stocks after negative earnings surprises (Columns (3) and (4)). Whereas for liquid stocks, traders continue to disagree, the proportion of ISO sell volume for illiquid stocks rises by 6% more than the proportion of ISO buy volume, and $\triangle$ is negative and significant at 1%. These findings suggest that a significant jump in the proportion of ISO volume for illiquid stocks immediately after an announcement release, observed in Figure 1, is mainly driven by an increase in the trading aggressiveness on the sell side after negative announcement releases.

Overall, aggressive traders largely disagree after positive earnings surprises and strongly agree after negative earnings surprises in the sample of illiquid stocks, which tend to be more short-sale constrained and have larger information asymmetry between investors prior to an announcement release. Therefore, I expect aggressive trading to speed up price adjustment after negative news and slow down price adjustment after positive news in the sample of illiquid stocks. For liquid stocks, I expect the overall effect of trading aggressiveness to be negative, albeit less pronounced due to overall lower impact of ISOs on volatility of liquid stocks.

The definition of the end of the 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 drops back 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.

In the following, I use the non-parametric test, proposed by Smith et al (1997) to determine whether realized variance is abnormal in a given time interval. Specifically, I calculate realized variance within each ten-minute interval during an announcement period (event days 0 to 2) and compare it to realized variance of ten-minute intervals that lie in the same trading hour in the base period (event days -40 to -3). Realized variance is considered to be abnormal if it exceeds the 75% cutoff value in the base period ($AbnRealVar_t = 1$).[24]

[24] 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 longer (one-hour) sampling intervals.

To identify the end of the adjustment period, I order all intervals in the event window relative to the first ten-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 9:40 a.m. on the next day is numerated as period 7. The price ends its adjustment in the first interval for which the realized variance is no longer abnormal ($AbnRealVar_t = 0$), the average realized variance in the previous hour is abnormal ($\frac{1}{6}\sum_{j=t-1}^{t-6} AbnRealVar_j \geqslant 0.5$) and the average realized variance in the next hour is no longer abnormal ($\frac{1}{6}\sum_{j=t+1}^{t+6} AbnRealVar_j < 0.5$).[25] I censor adjustment time to the end of the second post-announcement day for 5% of announcements, for which realized variance does not cease to be abnormal.

Univariate results. Panel A of Table 10 displays the distribution of adjustment time (in minutes) across terciles of trading aggressiveness, separately for the samples of liquid and illiquid stocks. Terciles of trading aggressiveness (TA1 - TA3) in the post-Reg NMS period are based on changes in the proportion of ISO volume on announcement days relative to their mean in the base period ($\Delta ISOvol$). I drop stock-announcement outliers with $\Delta ISOvol$ in the lowest and highest 1% percentiles of the sample. TA3 comprises announcements with the highest increases in trading aggressiveness on event days and TA1 with the lowest. The last row in Panel A also reports mean adjustment times for total samples of liquid and illiquid stocks.

[Insert Table 10 approximately here]

The mean adjustment time for liquid stocks is 209 minutes or approximately 3.5 hours in the post-Reg NMS period. Illiquid stocks take on average one hour longer to converge. Interestingly, split by terciles of trading aggressiveness reveals different patterns across the two samples. For liquid stocks, adjustment time increases gradually from 190 minutes for stocks in TA1 to 220 minutes in TA3 (Column 1). By contrast, this relation has a U-shape in the sample of illiquid stocks, with stocks in TA1 tercile taking the longest 276 minutes to converge. TA3 stocks take almost as long: 263 minutes, whereas TA2 stocks end their adjustment on average 30 minutes earlier (Column 4).

[25] 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.

The longest adjustment time for TA1 stocks in illiquid sample is contrary to previous expectations. To investigate this issue in more detail, I report descriptive statistics by TA terciles in Panel B of Table 10. From the first two rows of Panel B it is evident that the proportion of ISO volume actually drops for TA1 stocks on an announcement date: by 7.7% for liquid and by 16.2% for illiquid stocks. TA1 stocks in the illiquid sample are on average smaller and have larger relative spreads than TA2 stocks. They are approximately comparable by their size and liquidity to TA3 stocks, but have lower earnings surprises (2.55% as compared to 4.09% for TA3 stocks). Arguably, these stocks do not attract a lot of attention from traders during their announcements and take longer to converge in the absence of active trading.

Next, I compare changes in adjustment times across terciles between two regulation regimes. For this purpose, I assign "pseudo"-terciles of trading aggressiveness for all announcements in the pre-Reg NMS period. Specifically, I calculate the median TA tercile for each stock after Reg NMS and assign this TA tercile for all announcements of this stock that happen prior to Reg NMS. Columns (3) and (6) of Panel A in Table 10 report differences in adjustment times between pre- and post-Reg NMS periods. For liquid stocks as well as for TA1 and TA2 illiquid stocks, mean adjustment time remained the same as before Reg NMS. Importantly, adjustment time for TA3 stocks in the illiquid sample has significantly increased by more than one hour. This result provides first empirical evidence that excess trading aggressiveness during announcement periods can be harmful for price adjustment of illiquid stocks.

Figure 3 illustrates relations between changes in adjustment times and changes in trading aggressiveness, estimated with Nadaraya-Watson kernel regression functions separately for samples of liquid and illiquid stocks.

[Insert Figure 3 approximately here]

Overall patterns are consistent with Table 10. Large increases in trading aggressiveness slow down the speed of price adjustment both for liquid and illiquid stocks. However, for liquid stocks changes do not exceed 15 minutes and are not economically significant. By contrast, adjustment time increases by more than 50 minutes for illiquid stocks with an increase in the proportion of ISO volume larger than 50%, which constitute a quarter of illiquid stocks in the post-Reg NMS period.

Regression analysis. Table 11 examines the relation between trading aggressiveness and speed of price adjustment in a multivariate setup. I include earnings announcements both from the pre- and post-Reg NMS period in all models to control for differences in adjustment times in the pre-Reg NMS period. Since each stock in the final sample has at least one announcement in each of the regulation periods, results are not influenced by differences in the underlying subsamples. Models (1) to (3) of Table 11 report results of negative binomial regressions with adjustment time, measured as the number of ten-minute intervals until realized variance is no longer abnormal, as the dependent variable.[26]

[Insert Table 11 approximately here]

The vector of explanatory variables consists of *Post Reg* that equals one if an announcement happens after the adoption of the Reg NMS, and zero otherwise; the positive change in the proportion of 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 ISO volume. I examine separately the effects of 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 for illiquid stocks (as suggested by the univariate results). I additionally control for the absolute value of earnings surprise, *Earn Surp;* percentage increase in volume traded on an announcement day from its base level, $\triangle Vol$; and the stock market volatility on an announcement day that is measured by Chicago Board Options Exchange Market Volatility Index, *VIX.* I expect the coefficient for $\triangle Vol$ 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. Among all control variables, only VIX is positive and significant.

The relation between increases in trading aggressiveness and speed of price adjustment is not significant for liquid stocks (Model 1). Consistent with the univariate results, if trading aggres-

[26]Negative binomial regressions account for skewness and overdispersion present in the count data.

siveness decreases, price adjustment is quicker, but this result is also not statistically significant. For illiquid stocks, this relation continues to exhibit a U-shape, but only the coefficient on positive changes of $\triangle ISOVol$ is significant. Since the benchmark value of the dependent variable equals the mean adjustment time for stocks before Reg NMS (214 minutes or around 3.5 hours, according to Panel A of Table 10), all coefficients should be interpreted as relative changes to adjustment time 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. The coefficient of 0.26 on $Illiq \cdot |\Delta ISOvol|_{\Delta>0}$ means that a 100% increase in the proportion of ISO volume slows down price adjustment by $e^{0.26} - 1 = 0.1735$ or 29.7% from the benchmark value to 277 minutes or 4.5 hours. This change of around one hour is statistically and economically significant.

Even though the coefficient for negative changes of $\triangle ISOVol$ is not significant, in economic terms it is as large as the corresponding coefficient on positive changes for illiquid stocks. This result is puzzling, but as suggested by univariate results, might be explained by the overall longer adjustment time of stocks with large decreases in trading aggressiveness. To check whether this is the case, I estimate regressions with standardized differences in adjustment time between pre- and post-Reg NMS periods as the dependent variable (see Model 4 of Table 11). The coefficient on positive changes in trading aggressiveness is still positive and significant at 1%, whereas coefficient on negative changes loses its significance. So far, results in Models (1) and (4) suggest that large increases in trading aggressiveness significantly increase adjustment times of illiquid stocks, as compared to their adjustment time in the pre-Reg NMS period.

Robustness checks. Since the average price of illiquid stocks, \$21.8, is lower than the average price of liquid stocks, \$31.7, larger deviations in realized variance of illiquid stocks on announcement days might be just mechanical. Therefore, the lower price of illiquid stocks could bias their adjustment time upwards and overestimate the effect of trading aggressiveness on the speed of their price adjustment. To account for the price level of illiquid stocks, I use the realized price range measure, proposed by Martens and van Dijk (2007), to define abnormal volatility on announcement days. Models (1) to (2) of Table 12 report results with the modified dependent variable for levels and differences in adjustment time, respectively. All of the previous findings are robust.

[Insert Table 12 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 Amihud measure of the stock in the base period is above the median for all stocks in the sample, and equals zero otherwise. Models (3) and (4) of Table 12 display results, which are again consistent with those of Table 11.

Disagreement between aggressive traders and the speed of price adjustment. Previous analysis from this section shows that positive news about less liquid stocks causes larger disagreement between aggressive traders, as compared to negative news. With an increase in aggressive trading both on the buy and sell side, price stabilization is more difficult and it should take longer for a stock to adjust. Therefore, I expect trading aggressiveness to have a more negative effect on the speed of price adjustment of illiquid stocks after positive earnings surprises. Models (2) and (3) of Table 11 confirm these expectations: the negative effect of trading aggressiveness for illiquid stocks dominates in the subsample with positive earnings surprises. A 100% increase in the proportion of ISO volume slows down the adjustment process of the illiquid stocks by 34%. As in Model (1), coefficient on $Illiq \cdot |\Delta ISOvol|_{\Delta<0}$ is large and now even significant at 10% level, but it loses its significance as soon as the dependent variable is changed to differences in adjustment time between pre- and post-Reg NMS periods (Model 5). After negative earnings surprises, the coefficient on increases in trading aggressiveness is still positive, but significant only at 10% level.

According to Diamond and Verrecchia (1987), the agreement after negative earnings surprises should be the highest for the most short-sale constrained stocks. Following Nagel (2005), I use institutional ownership of the stock as a proxy for short-sales constraints to test whether an increase in trading aggressiveness speeds up price adjustment of short-sale constrained stocks after negative earnings surprises. I obtain data on institutional ownership from FactSet Ownership database, constructed by Ferreira and Matos (2008), and extract the Total Institutional Ownership Ratio as a percentage of market capitalization (IO). I split the sample by the median IO and classify stocks as short-sale constrained if their IO is below the sample median ($Low\,IO$) and as not short-sale constrained otherwise ($High\,IO$).

Models (5)-(7) of Table 12 estimate effects of trading aggressiveness conditional on short-sale constraints of a stock. Since trading aggressiveness has a significant effect only in the subsample of illiquid stocks, I estimate Models (5)-(7) only for these stocks. The coefficient on increases in trading aggressiveness after negative earnings surprises is still positive but no longer significant for *Low IO* stocks (Model 7). This result suggests that large increases in trading aggressiveness do not speed up price adjustment even in situations when investors largely agree on the direction of the news. Model (6) reports results for the subsample of positive earnings announcements. Interestingly, an increase in trading aggressiveness significantly slows down price adjustment of short-sale constrained stocks, but has almost no effect on stocks with high levels of institutional ownership. Longer convergence times of short-sale constrained stocks after positive earnings announcements are overall consistent with the overshooting hypothesis of Miller (1977). High divergence of investor opinions after positive news and not enough opportunities for professional traders to short-sell the stock can lead to price overshooting, and a large increase in aggressive trading exacerbates this effect through further price destabilization.

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. For illiquid stocks, large increases in trading aggressiveness significantly slow down price adjustment, especially after positive earnings announcements when the majority of aggressive traders disagrees about the precise level of the new fundamental value. Contrary to prior expectations, aggressive trading in the direction of the news after negative earnings announcements does not speed up price adjustment, even in the sample of short-sale constrained stocks. Thus, the adverse effect of aggressive trading on excess intraday volatility seems by far and large to outweigh its potential positive effect on quick price movements in the direction of the new equilibrium value.

6 Conclusions

This paper analyzes how large increases in aggressive trading of US stocks after earnings announcements affect the speed of their price adjustment. 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 significantly slows down price adjustment of illiquid stocks. As compared to the pre-Reg NMS period, when aggressive orders were not yet available, illiquid stocks with largest increases in trading aggressiveness take around one hour longer to adjust. The effect is more pronounced after positive earnings announcements when aggressive traders largely disagree on the exact level of new fundamental value. Quick trading in different directions unnecessarily increases intraday volatility and makes 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 A

Variable Definitions

Variable	Description	Source
$1/P$	The inverse of the stock price (in $)	TAQ
$\Delta ISOvol$	The change in the proportion of volume that is executed with aggressive intermarket sweep orders (ISOs) after an announcement release until the end of the next trading day relative to its mean in the base period	TAQ
ΔVol	Percentage increase in volume traded on an announcement day from its base level	CRSP
Aggregate Size	Aggregate size (in shares) of all trades that are executed in the same second and in the same direction, calculated separately for ISOs and non-ISOs	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
Depth	Sum of shares available at the NBBO bid and NBBO ask (in thousands of shares)	TAQ
Earn Surp	The absolute value of a 24-hour post-announcement return	TAQ
Effective Spread	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	One for observations on the announcement date and 0 otherwise	I/B/E/S
High IO (Low IO)	One, if the institutional ownership of the stock is above (below) the median value of all stocks in the sample, and zero otherwise	FactSet Ownership

Variable	Description	Source
Illiquid (Illiq)	One, if the relative spread of the stock is above the median value of all 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
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
N Exch	Number of exchanges that offer depth at NBBO (either on the ask or on the bid side)	TAQ
Order Size	Size of a transaction (in shares)	TAQ
$Pos\,Overshoot_s$, $(Neg\,Overshoot_s)$	Mean absolute percentage quote overshooting after purchases (sales). See section 3.2 for calculation details.	TAQ
Pre-Reg NMS (Post-Reg NMS)	One, if an announcement happens before (after) the final implementation of the Regulation NMS (October 2007), and zero otherwise	
Prc	Stock price (in \$)	CRSP
Price Impact $(PrcImp_{t,s})$	The measure of the price impact of a trade, defined as $PrcImp_t = 2\left\|Q_{t+s} - Q_t\right\|/Q_t$, where Q_{t+s} is the NBBO midpoint price of the stock after s seconds	TAQ

Variable	Description	Source
Price Range *($PrcRng_s$)*	The intraday volatility measure of the realized price range, proposed by Martens and van Dijk (2007). It is defined as $PrcRng_s = \frac{(log\, H_s - log\, L_s)^2}{4\, log\, 2}$, where H_s is the maximum midpoint price within a given time interval s and L_s is the corresponding minimum midpoint price	TAQ
%ISOTrades	*Proportion of ISO trades:* The ratio of the number of intermarket sweep orders to the total number of orders executed within a given time interval (based on aggregate ISO trades)	TAQ
%ISOVol	*Proportion of ISO volume*: The ratio of the volume that is executed with intermarket sweep orders to the total volume traded within a given time interval	TAQ
%BuyTrades, *%SellTrades*	*Proportion of ISO purchases (sales):* The ratio of the number of purchase (sale) transactions that are executed with intermarket sweep orders to the total number of purchase (sale) transactions within a given time interval	TAQ
$\%BuyVolume$ $\%SellVolume$	*Proportion of ISO purchase (sale) volume*: The ratio of the volume of purchase (sale) transactions that are executed with intermarket sweep orders to the total volume of purchase (sale) transactions within a given time interval	TAQ
Realized Variance *($RealVar_s$)*	The intraday volatility measure of realized variance, calculated as the sum of the squared high-frequency quote midpoint returns within a given time interval s: $RealVar_s = \sum_{t=1}^{s}(log\, Q_t - log\, Q_{t-1})^2$.	TAQ

Variable	Description	Source
Relative Spread (RelSpr)	NBBO relative spread, prevailing at the time of trade execution. It is defined as the difference between the NBBO ask and the NBBO bid, scaled by their average; observations with *RelSpr*>*0.5* are set to missing values.	TAQ
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
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
$VWAP_{Buy}$ ($VWAP_{Sell}$)	Volume-weighted average price for buy (sell) orders, calculated separately for ISOs and non-ISOs (in $)	TAQ

Appendix B

TAQ Data Processing

I use data filters to clean trade and quote data, as described by Hendershott and Moulton (2011). For each second, I calculate the National Best Bid and Offer (NBBO) with the help of Hasbrouck (2010) algorithm.[27] First, the prevailing quote at the end of each second is identified for each exchange. Afterward, the best (maximum) bid (B_t) and the best (minimum) ask (A_t) is chosen across all exchange quotes. The midpoint price is calculated as the average of the prevailing bid and ask quotes: $Q_t = (A_t + B_t)/2$. I also record the total sum of shares available at the best bid and the best ask as well as the number of exchanges that quote the best bid and the best ask.

Trades are merged to the NBBO that prevails one second before the trade execution. Chakravarty et al (2012) try 0, 10, 50, 500, 1,000 and 5,000 millisecond lags and find that the highest percentage of ISO and non-ISO trades occurs at the quotes if merged with a lag of 1,000 milliseconds. I use Lee and Ready's (1991) algorithm to identify the direction of a trade. Trades with the transaction price (P_t) above the midpoint price ($P_t > Q_t$) are identified as buyer-initiated transactions and those with the transaction price below the midpoint price ($P_t < Q_t$) as seller-initiated transactions. If the transaction price is equal to the midpoint price, the current transaction price is compared with the previous transaction price. If $P_t < P_{t-1}$, I consider a trade to be seller-initiated; if $P_t > P_{t-1}$, I consider it to be buyer-initiated. Should the two prices be equal, the trade is left as unclassified. Papers by Odders-White (2000), Ellis, Michaely, and O'Hara (2000) and Theissen (2001) show that only 72% to 85% of trades are correctly classified as buyer- or seller-initiated with the Lee and Ready (1991) algorithm. However, the misclassification is fairly symmetric and it should not bias measures of ISO order imbalance (differences between an increase in ISO buy volume and in ISO sell volume), which is the only part of my results that uses the Lee and Ready algorithm.

[27] I would like to thank Joel Hasbrouck for making the SAS code of his algorithm available at http://people.stern.nyu.edu/jhasbrou/

Figure 1: **Changes in the Proportion of ISO volume on Earnings Announcement Dates.** This figure displays the mean percentage deviations in the proportion of ISO volume throughout the announcement day, separately for liquid and illiquid stocks. The deviations from the bootstrapped cross-sectional means are measured in 10-minute intervals relative to the 10-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 for liquid stocks, which is equal to 2.36%. The dash-dotted line shows the corresponding value for illiquid stocks equal to 5.26%

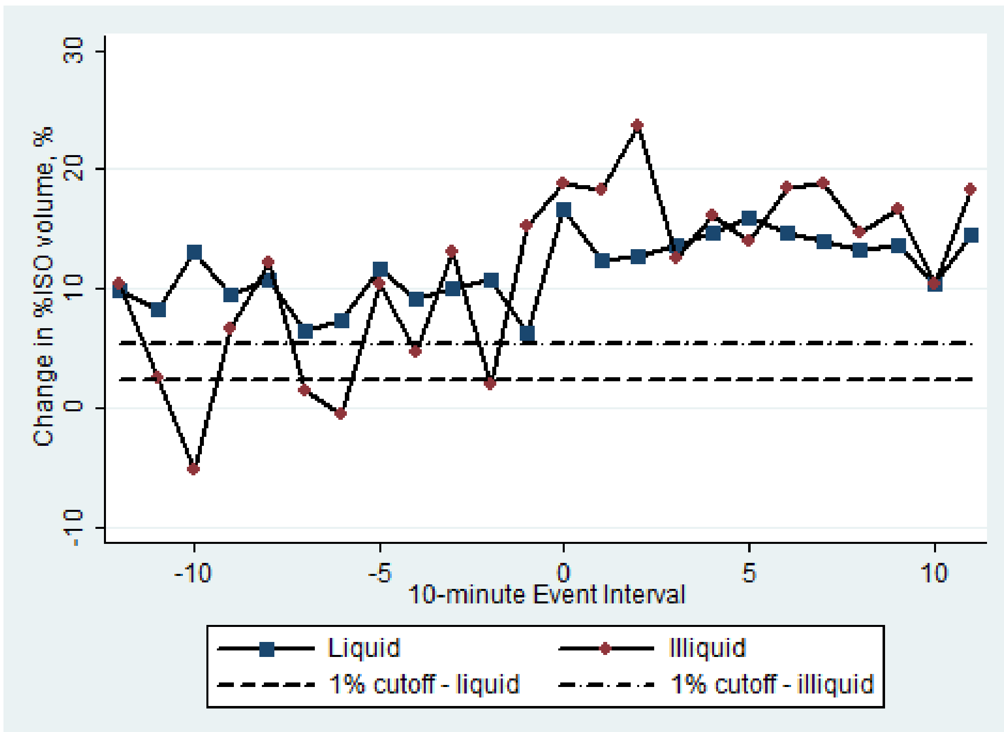
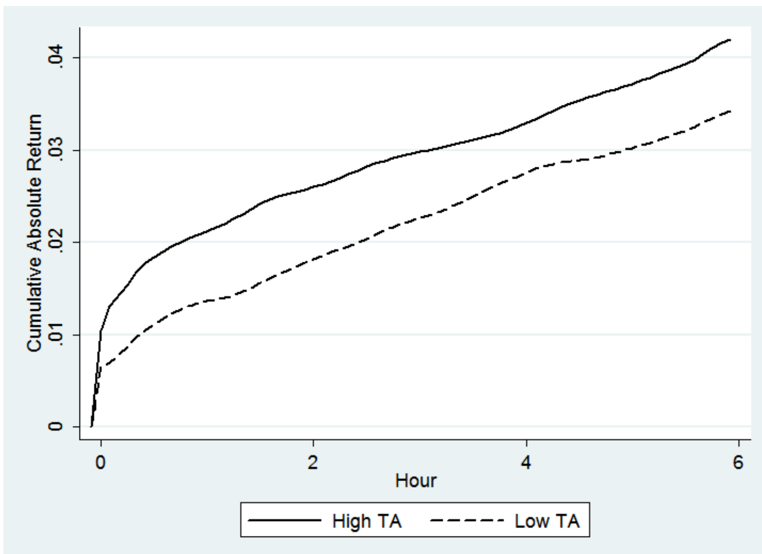


Figure 2: **Development of the Cumulative Intraday Returns and Abnormal Volatility over Time.** Panel A of this figure depicts the development of the cumulative absolute returns within the first six hours since an earnings announcement release (interval 0). I aggregate positive and negative earnings 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 interval on the non-announcement days [-40;-2].

A. Cumulative intraday post-announcement returns



B. Abnormal post-announcement volatility

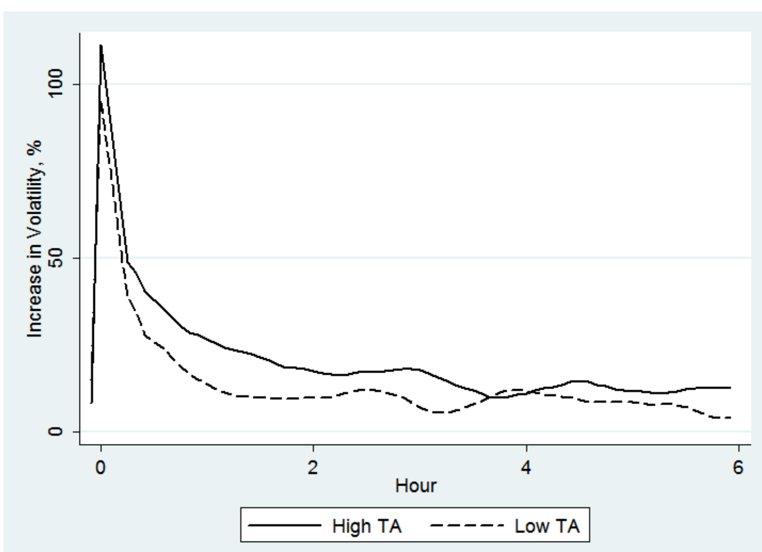
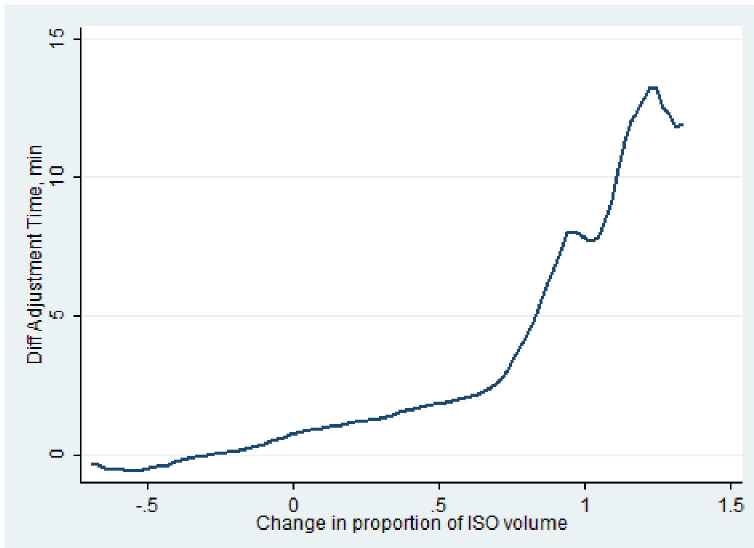


Figure 3: **Change in Adjustment Time and Trading Aggressiveness.** This figure illustrates relations between changes in adjustment times between pre- and post-Reg NMS period and changes in trading aggressiveness on announcement dates, estimated with Nadaraya-Watson kernel regression function. The length of the price adjustment period is measured as the number of ten-minute time intervals until the realized variance is no longer abnormal. Panel A illustrates the relation for liquid stocks and Panel B for illiquid stocks.

A. Liquid Stocks



B. Illiquid Stocks

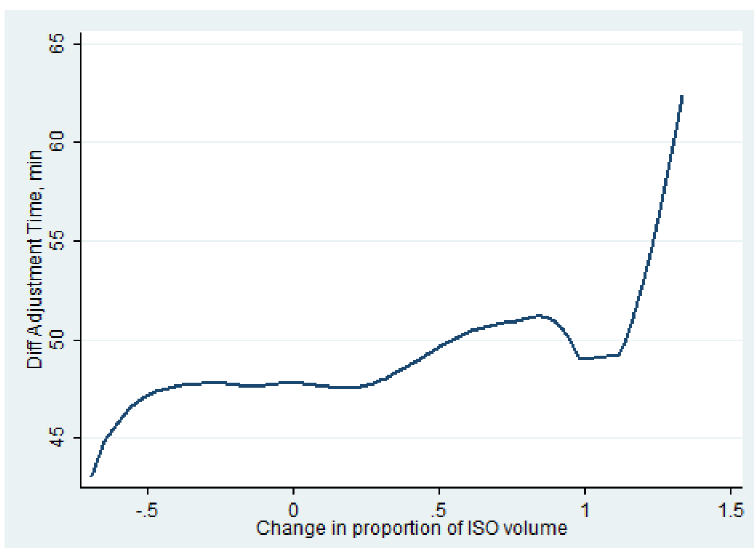


Table 3: **Sample Construction.** This table shows the sample selection of the earnings announcements of US firms that happened within trading hours (from 9:30 a.m. till 16:00 p.m. EST) from 2006 to 2009. The data source for dates and times of the earnings announcements is the Institutional Brokers Estimate System (I/B/E/S) database. I require each firm to exist in the intersection set of I/B/E/S and CRSP.

Criteria	**Announce-ments**	**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 4: **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 Appendix A 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 5: **Trading with Aggressive Orders: Bootstrap Analysis.** Panel A of this table summarizes proportions of trades ($\%ISOTrades$) and volume ($\%ISOVol$) traded with intermarket sweep orders (ISOs) in the base period and during earnings announcement releases. Column (1) displays the mean of the bootstrapped distribution for ISOs from the base period, consisting of days [-40;-2] preceding the announcement date. Column (2) reports the cross-sectional mean of the respective variables on an announcement day. Columns (3)-(4) and (5)-(6) report the same statistics separately for subsamples of liquid and illiquid stocks, correspondingly. A stock is defined as illiquid if its relative spread is above the median value of all of the stocks in the sample. Panel B summarizes differences in trading characteristics between ISOs and non-ISOs in the base period (Columns (1) and (2)) and during earnings announcement releases (Columns (3) and (4)). See Appendix A for the exact definition of all variables. P-values of the t-test for the null-hypothesis that the difference in means between ISOs and non-ISOs equals zero are calculated using bootstrapped standard errors. * denotes statistical significance at the 10% level, ** - at the 5% level, and *** - at the 1% level..

Panel A: Base Period vs Post-Announcement Period

	Total			Liquid			Illiquid		
	(1)	(2)		(3)	(4)		(5)	(6)	
	Base	Event		Base	Event		Base	Event	
%ISOTrades	36.75	40.66	***	37.77	41.40	***	35.76	39.93	***
%ISOVol	36.16	40.57	***	37.27	41.36	***	35.11	39.78	***
%BuyTrades	37.35	40.57	***	37.71	41.21	***	36.94	39.85	***
%BuyVolume	36.96	40.44	***	37.45	41.25	***	36.41	39.50	***
%SellTrades	36.37	40.62	***	37.88	41.42	***	34.74	39.77	***
%SellVolume	35.69	40.57	***	37.27	41.34	***	33.99	39.75	***

Panel B: ISO vs non-ISO orders

	Base Period			Event Day		
	(1)	(2)		(3)	(4)	
	ISO	Non-ISO		ISO	Non-ISO	
Order Size (in shares)	176	209	***	180	212	***
Aggregate Size (in shares)	290	293		310	309	
VWAP_{Buy}	24.88	24.57		24.41	23.92	**
VWAP_{Sell}	24.29	24.05		23.96	23.51	**
Effective Spread, %	1.19	1.15		1.38	1.35	
Relative Spread, %	0.96	1.01	**	1.00	1.05	**

Table 6: **Determinants of intraday ISO trading volume.** This table reports results of panel data OLS regressions with proportion of ISO volume ($\%ISOvol$) as the dependent variable. One observation represents a ten-minute trading interval for a stock. See Appendix A for the exact definition of all variables. Model (1) reports results for the base period. Models (2)-(4) report results for the full announcement day, for pre-announcement period and post-announcement period, correspondingly. All regressions include year-fixed effects and intraday dummies for each half-hour of the trading day. Standard errors allow for clustering at the firm level. 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) Total	(2) Event	(3) Pre-Event	(4) Post-Event
L1.%ISOvol	0.2493 ***	0.2204 ***	0.2136 ***	0.2246 ***
L2.%ISOvol	0.1850 ***	0.1522 ***	0.1653 ***	0.1423 ***
L3.%ISOvol	0.1704 ***	0.1507 ***	0.1658 ***	0.1401 ***
RelSpr	-0.9336 ***	-1.6394 **	-3.5166 ***	-0.7247
$RealVar_{-5sec}$	4.4963 ***	5.1873 ***	4.4760 ***	5.5370 ***
N exch	-0.0092 ***	-0.0100 ***	-0.0103 **	-0.0097 ***
Depth	-0.0005 ***	-0.0002	-0.0008	-0.0001
EarnSurp		0.0102	-0.0215	0.0183
N	1475730	30778	12259	18519
R-squared	0.24	0.15	0.16	0.15
Daytime FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Table 7: **Intraday Price Impact and Volatility: Bootstrap Analysis.** This table summarizes differences in intraday price impact and volatility between ISOs and non-ISOs for different time periods relative to trade execution. See Appendix A for the exact definition of all variables. Columns indicate time period, in which the intraday price impact and volatility is measured relative to the time of trade execution. Columns (1) and (2) display means of the bootstrapped distribution in the base period, measured 5 seconds before the trade, separately for ISOs and non-ISOs. Columns (3)-(4) report the corresponding figures 1 second after the trade, Columns (5)-(6) - 5 seconds after the trade, and Columns (7)-(8) - 1 minute after the trade. Panel A presents results for liquid stocks and Panel B - for illiquid stocks. A stock is defined as illiquid if its relative spread is above the median value of all of the stocks in the sample in the base period. P-values of the t-test for the null-hypothesis that the difference in means between ISOs and non-ISOs equals zero are calculated using bootsrapped standard errors. * denotes statistical significance at the 10% level, ** - at the 5% level, and *** - at the 1% level..

Panel A: Liquid Stocks

	-5 sec		1 sec			5 sec			1 min		
	ISO	Non-ISO	ISO	Non-ISO		ISO	Non-ISO		ISO	Non-ISO	
Price Impact	0.00018	0.00018	0.00031	0.00023	***	0.00041	0.00032	***	0.00076	0.00066	***
Realized Variance	0.00045	0.00043	0.00040	0.00031	***	0.00108	0.00088	***	0.00539	0.00481	*
Price Range	0.00011	0.00010	0.00011	0.00008	***	0.00024	0.00019	***	0.00065	0.00058	*
Pos Overshoot	0.00029	0.00030	0.00068	0.00058	***	0.00081	0.00072	***	0.00093	0.00087	
Neg Overshoot	0.00027	0.00028	0.00065	0.00054	***	0.00077	0.00067	***	0.00089	0.00082	

Panel B: Illiquid Stocks

	-5 sec		1 sec			5 sec			1 min		
	ISO	Non-ISO	ISO	Non-ISO		ISO	Non-ISO		ISO	Non-ISO	
Price Impact	0.00046	0.00049	0.00182	0.00117	***	0.00235	0.00161	***	0.00339	0.00259	***
Realized Variance	0.00047	0.00045	0.00090	0.00064	***	0.00182	0.00138	***	0.00587	0.00474	***
Price Range	0.00012	0.00011	0.00025	0.00017	***	0.00047	0.00036	***	0.00102	0.00084	***
Pos Overshoot	0.00034	0.00036	0.00153	0.00115	***	0.00192	0.00150	***	0.00234	0.00195	***
Neg Overshoot	0.00029	0.00028	0.00152	0.00103	***	0.00189	0.00133	***	0.00230	0.00170	***

Table 8: **Intraday Price Impact and Volatility: Regression Analysis.** This table reports results of panel data OLS regressions with time-fixed effects. One observation represents a ten-minute trading interval for a stock. Dependent variables in Models (1)-(5) are as follows: intraday price impact ($PrcImp_{+5s}$), realized variance ($RealVar_{+5s}$), realized price range ($PrcRng_{+5s}$), percentage overshooting after purchases ($PsOvrsht_{+5s}$) and percentage negative overshooting after sales ($NgOvrsht_{+5s}$). All dependent variables are measured 5 seconds after the trade separately for ISOs and non-ISOs and subsequently averaged over 10-minute intervals. See Appendix A for the exact definition of all variables. All regressions include year-fixed effects and intraday dummies for each half-hour of the trading day. Standard errors allow for clustering at the firm level. 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) PrcImp	(2) RealVar	(3) PrcRng	(4) PsOvrsht	(5) NgOvrsht
L1.DepVar	0.15541 ***	0.37512 ***	0.37077 ***	0.24147 ***	0.22918 ***
L2.DepVar	0.12162 ***	0.21037 ***	0.21411 ***	0.15946 ***	0.15269 ***
L3.DepVar	0.08288 ***	0.16697 ***	0.17228 ***	0.12997 ***	0.12069 ***
ISO	0.00001 **	0.00003 ***	0.00001 ***	0.00001 ***	0.00002 ***
RelSpr	0.05515 ***	0.03915 ***	0.00800 ***	0.08704 ***	0.07449 ***
ISO · RelSpr	0.02728 ***	0.01194 ***	0.00297 ***	0.01359 ***	0.00739 **
$1/P$	0.00054 ***	0.00115 ***	0.00028 ***	-0.00020	0.00010
Volume	-0.00000 ***	0.00000 ***	0.00000 ***	-0.00000 ***	-0.00000 ***
VIX	0.00013 ***	0.00084 ***	0.00019 ***	0.00046 ***	0.00037 ***
N	2567719	2567719	2567719	1623861	1632645
R-squared	0.24	0.48	0.49	0.28	0.26
Daytime FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Table 9: **Disagreement between aggressive traders after earnings announcements.** This table examines disagreement between aggressive traders in pre-announcement periods by computing differences in the means between an increase in the proportion of ISO buy volume and an increase in the proportion of ISO sell volume :$\Delta = \Delta_{Buy} - \Delta_{Sell}$, where $\Delta_{Buy} = \%BuyVolume_{Event} - \%BuyVolume_{Base}$, and $\triangle_{Sell}$ is calculated in a similar way. The mean proportions of ISO buy and sell volume in the base period are based on the bootstrap distribution for each stock. A positive (negative) earnings surprise is defined by the direction of the 24-hour post-announcement return. Columns (1) and (2) present results after positive earnings surprises for liquid stocks and illiquid stocks, respectively. Columns (3) and (4) present results after negative earnings surprises. P-values are based on bootsrapped standard errors. * denotes statistical significance at the 10% level, ** - at the 5% level, and *** - at the 1% level.

	Pos EarnSurp				Neg EarnSurp			
	(1)		(2)		(3)		(4)	
	Liq		Illiq		Liq		Illiq	
$\%BuyVolume_{Event}$	42.5%		41.8%		42.8%		37.9%	
$\%BuyVolume_{Base}$	38.7%		37.7%		38.3%		36.9%	
$\triangle_{Buy}$	3.78%	***	4.01%	***	4.44%	***	0.99%	
$\%SellVolume_{Event}$	42.4%		41.1%		43.1%		46.2%	
$\%SellVolume_{Base}$	39.0%		39.2%		38.7%		39.2%	
$\triangle_{Sell}$	3.38%	***	1.89%		4.34%	***	7.01%	***
$\triangle$	0.40%		2.11%		0.10%		-6.02%	***

Table 10: **Price Adjustment and Trading Aggressiveness: Summary Statistics and Univariate Analysis.** Panel A of this table presents the distribution of adjustment time (in minutes) across terciles of trading aggressiveness separately for the samples of liquid (Columns 1-3) and illiquid (Columns 4-6) stocks. 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 ($\Delta ISOvol$). TA1 comprises announcements with the lowest increases in trading aggressiveness on an announcement day and TA3 comprises announcements 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. P-values of the t-test for the null-hypothesis that the difference in means between adjustment times in pre- and post-Reg NMS periods equals zero are reported to the right of Columns 3 and 6. * denotes statistical significance at the 10% level, ** - at the 5% level, and *** - at the 1% level. . Panel B displays descriptive statistics by TA terciles, separately for liquid and illiquid stocks. See Appendix A for the exact definition of all variables.

Panel A: Speed of Price Adjustment: Summary Statistics

	Liquid			Illiquid			
	Post-Reg NMS	Pre-Reg NMS	$\triangle$	Post-Reg NMS	Pre-Reg NMS	$\triangle$	
	(1)	(2)	(3)	(4)	(5)	(6)	
TA1	190	214	-24	276	262	14	
TA2	215	206	9	232	221	11	
TA3	220	209	11	263	195	68	***
Total	209	208	1	271	221	50	***

Panel B: Descriptive Statistics by Aggressiveness Tercile

	Liquid			Illiquid		
	TA1	TA2	TA3	TA1	TA2	TA3
	(1)	(2)	(3)	(4)	(5)	(6)
$\%ISOVol_{Base}$	42.1%	40.7%	27.4%	37.2%	39.2%	31.9%
$\%ISOVol_{Event}$	34.4%	43.9%	46.1%	21.0%	43.3%	59.0%
Mcap (in mln $)	5088	5627	2756	128	196	121
RelSpr	0.26%	0.23%	0.26%	2.30%	1.52%	2.43%
EarnSurp	3.11%	3.15%	3.01%	2.55%	3.52%	4.09%

Table 11: **Price Adjustment and Trading Aggressiveness: Regression Analysis.** Models (1) to (3) of this table present results of 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 that is measured as the number of ten-minute intervals until the realized variance is no longer abnormal. Models (4) to (6) report results of OLS regressions with standardized differences in adjustment times between pre- and post-Reg NMS periods as the dependent variable. Models (1) and (4) report results for the total sample, Models (2) and (5) for positive earnings surprises, and Models (3) and (6) for negative earnings surprises. See Appendix A for the exact definition of all variables. All Models include weekday-, daytime- and year-fixed effects. 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, ** denotes statistical significance at the 5% level, *** denotes statistical significance at the 1% level. I also report the number of observations (N) and the p-value of the Likelihood-ratio test with the null hypothesis that the dispersion parameter is zero for negative binomial regressions. For OLS regressions, I report p-value of F-test on joint significance of explanatory variables.

	Adj Time			△ Adj Time		
	(1) Total	(2) Pos Surp	(3) Neg Surp	(4) Total	(5) Pos Surp	(6) Neg Surp
Post Reg	-0.049	-0.054	-0.052	-0.011	-0.065	0.011
Liq$\cdot \|\Delta ISOvol\|_{\Delta>0}$	0.040	0.095	-0.002	-0.008	0.012	0.007
Liq$\cdot \|\Delta ISOvol\|_{\Delta<0}$	-0.505	-0.353	-0.660	-0.408	-0.237	-0.542
Illiq$\cdot \|\Delta ISOvol\|_{\Delta>0}$	0.259 ***	0.295 ***	0.210 *	0.172 ***	0.197 **	0.136
Illiq$\cdot \|\Delta ISOvol\|_{\Delta<0}$	0.268	0.533 *	-0.066	-0.129	0.215	-0.318
Earn Surp	-0.388	-0.750	0.206	-0.272	-0.286	-0.132
ΔVol	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001
VIX	0.584 **	0.561 *	0.583 *	0.529 ***	0.513 **	0.520 **
N	3519	1772	1708	3481	1753	1689
P	0.000	0.000	0.436	0.000	0.000	0.215
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 12: **Price Adjustment and Trading Aggressiveness: Robustness Checks and Institutional Ownership Analysis.** Models (1) and (2) of this table present results with alternative definition of intraday volatility that is measured as the realized price range in each 10-minute interval. Models (3) and (4) use the Amihud (2002) illiquidity measure to split the sample between liquid and illiquid stocks. Models (5)-(7) analyze adjustment times in the sample of illiquid stocks, additionally controlling for short-sales constraints, proxied by institutional ownership of a stock. The dependent variable in Models (1), (3) and (5)-(7) is the length of the adjustment period that is measured as the number of the ten-minute intervals until the price ends its adjustment. Models (2) and (4) report results of OLS regressions with changes in adjustment times between pre- and post-Reg NMS periods as the dependent variable. Model (5) reports results for all stocks, classified as illiquid in the final sample, Model (6) for positive earnings surprises, and Models (7) for negative earnings surprises. See Appendix A for the exact definition of all variables.

	Price Range		Amihud		IO: Illiquid		
Adj Time (AT)	(1) AT	(2) △ AT	(3) AT	(4) △ AT	(5) Total	(6) Pos Surp	(7) Neg Surp
Post Reg	-0.063	-0.107	-0.071	-0.016	-0.121	0.072	-0.225
Liq$\cdot \lvert\Delta ISOvol\rvert_{\Delta>0}$	-0.188	-0.005	0.063	-0.020			
Liq$\cdot \lvert\Delta ISOvol\rvert_{\Delta<0}$	-0.661 *	-0.285	-0.468	-0.428			
Illiq$\cdot \lvert\Delta ISOvol\rvert_{\Delta>0}$	0.301 ***	0.103 *	0.245 ***	0.169 ***			
Illiq$\cdot \lvert\Delta ISOvol\rvert_{\Delta<0}$	0.477 **	-0.306 *	0.242	-0.141			
High IO$\cdot \lvert\Delta ISOvol\rvert_{\Delta>0}$					0.095	-0.022	0.142
High IO$\cdot \lvert\Delta ISOvol\rvert_{\Delta<0}$					-0.358	0.118	-1.029 *
Low IO$\cdot \lvert\Delta ISOvol\rvert_{\Delta>0}$					0.290 ***	0.349 **	0.146
Low IO$\cdot \lvert\Delta ISOvol\rvert_{\Delta<0}$					0.389	0.694	0.019
Earn Surp	-0.536	-0.398	-0.389	-0.271	-1.586 **	-1.296	-1.781
ΔVol	0.000	0.000	-0.000	-0.000	0.000	0.001	-0.009
VIX	0.101	0.088	0.593 **	0.534 ***	0.260	-0.146	0.438
N	3519	3481	3519	3481	1719	878	811
P	0.000	0.000	0.000	0.000	0.002	0.009	0.273
Weekday FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Daytime FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes