Early Peek Advantage?

Grace Xing Hu, Jun Pan, and Jiang Wang[*]

November 29, 2013

Abstract

From 2007 to June 2013, a small group of fee-paying, high-speed traders receive the results of the Michigan Index of Consumer Sentiment (ICS) from Thomson Reuters at 9:54:58, two seconds before the broader release. Focusing on the trading and price behavior in E-mini S&P 500 futures, we find that this tiered information release results in highly concentrated and coordinated trading by high-speed traders during the first second of the early peek window at 9:54:58. It also leads to super fast price discovery. Most of the price adjustment in reaction to the ICS news is accomplished during the first 10% of the trades at 9:54:58, which lasts about 15 milliseconds. More important, we find no evidence of further price drift after the initial price discovery. The scope of the early peek advantage is therefore narrowly contained within a time window populated mostly by the fee-paying, high-speed traders. Outside of this narrow window, general investors trade at fully adjusted prices and is not disadvantaged by the early peek of a few. On the contrary, our further results suggest that such concentrated trading among high-speed traders with pre-arranged early peek might actually be beneficial in the sense that they help improve the efficiency of price discovery.

1 Introduction

How information actually transmits and impounds into market prices remain a central question in our understanding of how financial markets function.[1] Empirical investigations aimed at tackling this question are hindered by the fact that most information is private in nature and hence not openly observable, even *ex post*. The multi-tiered process adapted by some data vendors in feeding market-moving information to their different clients offers a rare instance where we know precisely what information is transmitted, when and to what subset of market participants. This situation allows us to examine with more clarity how information, private to some traders, drives their trading behavior and influences the market.

The University of Michigan Index of Consumer Sentiment (ICS), which is based on nationwide telephone surveys of consumers, has long been considered a key reading of the U.S. consumer confidence. It is released bi-monthly and has been closely watched, and substantial changes in ICS often move financial markets. Since 2007, Thomson Reuters has obtained the exclusive rights in disseminating the results of the survey, including the reading of the index. In doing so, Thomson Reuters adapted a two-tiered process, sending the readings of ICS to a small group of fee-paying, high-speed clients at 9:54:58, two seconds earlier than the broader release at 9:55:00. Since June 2013, this practice has attracted wide news coverage, as well as a review by the office of New York Attorney General. In July 2013, less than one month after the initial coverage, Thomson Reuters decided to suspend the program.[2]

A series of questions were raised: To what extent does this tiered information release give an advantage to those with early information and how do they utilize it? To what extent are general investors hurt by this practice and does it damage the integrity of the markets? In which way does this process of tiered information release affect the informational efficiency of price discovery in financial markets? Specifically, what is the speed of price discovery with and without this mechanism of tiered information release?

In order to answer these questions, we examine in detail the price dynamics and trading activity in E-mini S&P 500 futures around ICS releases during this episode. Our overall

---

[1]There is an extensive theoretical literature illustrating how private information can be incorporated into market prices. See, for example, Grossman (1976), Grossman and Stiglitz (1980), Kyle (1985), Wang (1993), and He and Wang (1995). Most of the theoretical analysis, however, relies on highly stylized models regarding information structure and investor behavior with limited empirical basis.

[2]See, for example, *"Thomson Reuters Gives Elite Traders Early Advantage"* and *"Thomson Reuters Suspends Early Distribution of Consumer Data,"* reported by CNBC on June 12 and July 8, 2013, respectively.

findings paint the picture of a super narrow window of informational advantage enjoyed by those fee-paying, high-speed traders. The prices are fully adjusted to the ICS news after the first 10% of the trades during 9:54:58, which lasts about 14 to 16 milliseconds. There is no evidence of further price drift after the initial price discovery. This implies that most of the transactions during 9:54:58 and all the transactions afterwards, including the public announcement at 9:55:00, are traded at the fully adjusted market prices. The scope of the early peek advantage is therefore narrowly contained and limited to high-speed traders trading amongst themselves. Outside of this narrow window, general investors, as well as high-speed traders, trade at fully adjusted prices and are not disadvantaged by the early peek of a few.[3]

The initiation and later suspension of the early peek program by Thomson Reuters also provides a natural experiment for us to examine how different mechanisms of information release might impact the speed of price discovery. Associated with the early peek program is highly concentrated trading amongst those fee-paying, high-speed traders over a span of two seconds. As a result of this intense and coordinated trading, we see a super fast price discovery in the order of 14 to 16 milliseconds. After the suspension of the early peek program, however, we do not see the same level of trading intensity and we find that the price discovery takes much longer.[4] From this perspective, one might argue that, as a mechanism of information release, the tiered program provides a venue to facilitate concentrated and coordinated trading among informed high-speed traders and therefore makes price discovery more efficient.

We focus our empirical investigation on S&P 500 futures because ICS, reflecting consumers opinions of the general economy, is likely to move the entire market instead of individual stocks. Compared with the cash market products, E-mini S&P 500 futures is more liquid and less affected by short-sale constraints. It is thus an ideal financial instrument to trade on both positive and negative market-wide information.[5] From January 2008 to June

---

[3]This conclusion assumes that the early peek arrangement is fully public and consequently the general investors would optimally avoid the 2-second window in trading when they may be informationally disadvantaged. We present the evidence on both of these assumptions later in the paper.

[4]Our results are still preliminary since there are only 7 ICS news releases after Thomson Reuters suspended their early distribution program.

[5]Among E-mini Futures of varying maturity, we choose the most active contract with the highest volume, which is usually the nearest-term contract and occasionally the next contract during rolling forward weeks. Overall, we expect these contracts to be where informational trading takes place. We also examine the trading and pricing behavior in SPDR S&P 500 ETF and find very similar results. One could also imagine

2013, when Thomson Reuters offers early peek advantage, we find abnormally high trading volume of E-mini S&P 500 futures at 9:54:58 on ICS announcement days.[6] On average, the trading volume jumps to 1,473 contracts per second at 9:54:58, well above the sample average of 124 contracts per second. In terms of dollar trading volume, the transactions at 9:54:58 are close to $90 millions, compared with the sample average of $7.6 millions. One second later at 9:54:59, the abnormal volume drops to 261 contracts, still well above the sample average but sharply down from the trading volume at 9:54:58. In other words, although those fee-paying, high-frequency traders have an advantage of two seconds ahead of general investors, the first second at 9:54:58 is disproportionally more meaningful to them.

On non-ICS announcement Fridays, for the same sample period from January 2008 to June 2013, we do not find any abnormal trading volume at 9:54:58 or 9:54:59. For the period before the early peek arrangement, from 1997 through 2006, we also do not find any abnormal trading volume at those two seconds. Moreover, the abnormally high trading volume at 9:54:58 and 9:54:59 has since disappeared after July 2013, when Thomson Reuters decided to suspend its early distribution of ICS data. Compiling these information together, there is very little doubt that the abnormal trading volume at 9:54:58 and 9:54:59 is linked to the early peek mechanism devised by Thomson Reuters.

To better understand the price impact of early trading, we sort the announcement days into three groups depending on what directions ICS moves the market during the early peek window. The low and high groups contain the announcement days when ICS has "surprises" and moves the E-mini S&P 500 futures market down and up, respectively, by at least one tick during the two-second early peek window of 9:54:58 and 9:54:59. By contrast, the medium group contains the announcement days when the market does not respond to the ICS announcement over the two-second early peek window. Not surprisingly, trading volume is higher for days when ICS contains more information. The average one-second trading volume at 9:54:58 is 2,393 and 1,195 contracts, respectively, for the low and high group, while the one-second volume for the medium group is 271 contracts. But even for the medium group, when ICS announcement does not move price, the average trading volume of 271 contracts per second at 9:54:58 is still well above the sample average of 124 per second.

Just as high trading volume is clustered at 9:54:58, most of the price adjustment happens

---

Index options as such S&P 500 index options as a suitable venue to trade on such information.

[6]In this paper, what is referred to as volume or return at a given second, say 9:54:58, really means the volume or return during the second.

during the first second as well. For days in the low group when market reacts negatively to ICS announcement during the early peek window, the one-second return at 9:54:58 is -6.58 bps with a t-statistics of -7.39, while the return at 9:54:59 is only -0.49 bps with a marginal significant t-statistics of -1.90. For the high group, the return at 9:54:58 is 4.59 bps with a t-statistics of 8.04, while the return at 9:54:59 is 1.21 bps with a t-statistics of 4.10. More important than the returns at 9:54:58 and 9:54:59 is the price movement after 9:55:00, when the early peek window closes and the ICS results are announced to other investors. For all three groups, there is no significant further price drift in the one minute trading window after the public announcement. In other words, because of the early, concentrated trading at 9:54:58, the information contained in ICS has been fully impounded into E-mini futures prices. By 9:55:00 when general investors receive the news, ICS is no longer a profitable trading signal. Instead, the general investors trade at the fully adjusted market prices.

The speed of price discovery can be calibrated at a finer scale. We divide all transactions during 9:54:58 equally into 10 time intervals, with each time interval containing 10% of the total trades during the second. We find that, for the low group, the first 10% of the trades during 9:54:58 moves the market price at an average return of -5.78 bps, which accounts for 88% of the one-second return at 9:54:58. For the high group, the first 10% moves the market price at an average return of 4.20 bps, accounting for 92% of the total return in the full second of 9:54:58. In other words, most of the price discovery happens within the first 10% of the trades, which on average takes place within 14 to 16 milliseconds on ICS announcement days.[7] The blink of an eye takes place between 300 to 400 milliseconds. Similarly, transaction volume is also disproportionally concentrated during the first 10% of the trades. For the low and high group, respectively, over 48% and 39% of the total transaction volume takes place during the first 10% of the trades at 9:54:58. Compared with the super fast adjustment in price, however, transaction volume seems to be more persistent: the remaining 90% of the trades during 9:54:58 accounts for over 50% of the total volume over the entire second. But these transactions are traded at fully adjusted price and are not important in price discovery.

Given the narrow scope of informational advantage, one might question why traders with early peek information still trade in large volume even after market prices have already adjusted to the ICS information. Similarly, why do we observe abnormally high trading

_____

[7]Because the CME data used for our study is time-stamped only to seconds, we turn to a smaller sample from a private source to estimate trading time in milliseconds. The private data contains E-mini S&P 500 futures transactions time-stamped to milliseconds, but covers a shorter period from May 2012 to June 2013.

volume at 9:54:58 on days in the medium group when the ICS news does not move market price? A likely explanation is that a large portion of the early trading volume originates from "rebalancing" needs. The need to re-balance can come from two sources. One is to unwind existing positions built by high-speed traders before the early peek window, presumably based on their private information about the index. Their advance look at the ICS results helps them to neutralize their positions, realizing gains or loses and reducing unnecessary exposures to risk.[8] Another source of rebalancing need is to adjust positions in response to the new price levels. In both of these cases, instead of taking advantage of "uninformed" traders, a majority of the transactions within the early peek window are traded amongst "informed" high-frequency traders themselves.[9]

Our paper contributes to the existing empirical literature on price discovery using public information. For example, Balduzzi, Elton, and Green (2001) and Fleming and Remolona (1999) document the effects of public news release on Treasury bond prices, trading volume and liquidity; Andersen, Bollerslev, Diebold, and Vega (2003) focus on how exchange rates in the FX market respond to macroeconomic news. Our work distinguishes from this literature in two important dimensions. The first and the most crucial difference is in the nature of the information structure. Unlike the existing studies that focus only on public news, our paper takes advantage of the multi-tiered news release process adapted by Thomson Reuters. Consequently, the information structure is richer and more precise: the news is private to a number of high-frequency traders at exactly two seconds before the public release. This feature of selective disclosure gives us an unique opportunity to study how private information is priced into market through concentrated trading among a certain group of market participants. Second, taking advantage of high-frequency trading, we are able to document the speed of price discovery in the order of seconds and milliseconds. By comparison, the previous work has mostly focused on the one- to five-minute windows.

Our paper is also related to the recent studies on high-frequency trading and its impact

---

[8]As shown in He and Wang (1995), the current volume is not only related to the contemporaneous information flow, but also related to existing private information received previously. As a result, volume can reach its peak many periods after investors first receive private information.

[9]For the volume during the price discovery process (in the first 15 milliseconds), there does exist the possibility that one side of a transaction is trading at prices not fully reflecting the news. But we don't see any systematic pattern in these kind of trades. In any case, these trades are among high-frequency traders anyway, merely reflecting competition among themselves. It is also worth pointing out that we assume the market is fully aware of the early peek advantage. Thus, general investors should avoid trading in the first second or the first 15 millisecond of 9:54:58. See, for example, He and Wang (1995).

on price discovery.[10] Because of the exclusive nature of the two-second early peek, the setup in our paper is more clean cut than the existing papers in the literature: price discovery during the first 15 milliseconds happens overwhelmingly among concentrated high-frequency trading, with very little involvement of other market participants. The later suspension of the early peek arrangement by Thomson Reuters also offers a natural experiment for us to investigate how sensitive the speed of price discovery is to the early-peek mechanism. Our sample is very limited because we only have seven ICS announcements since July 2013. Nevertheless, the results clearly indicates that the futures market takes longer to incorporate the information content of ICS post the early peek arrangement.

The rest of paper is organized as follows. Section 2 gives a describes the early peek arrangement. Section 3 summarizes the data used in this paper. Section 4 reports the main results on abnormal early trading volume and the price impact of early trading. Section 5 concludes the paper. In the Appendices, we report the results for the cash market and investigate the potential early slippage at 9:54:57.

2   Background on Early Peek Arrangement

The Index of Consumer Sentiment (ICS) was created by the University of Michigan through nationwide telephone surveys and is a measure of consumer confidence with respect to the state of the economy. Considered as a key reading of consumer confidence, the public release of this closely watched index can often move financial markets, in ways similar to the release of official government data such as GDP, inflation and unemployment numbers. But unlike data released by the government, where painstaking efforts have been made to allow equal access for all investors, there are few regulatory rules on how private agencies release their own data. In 2007, Thomson Reuters reached a deal with the University of Michigan for exclusive distribution rights of ICS, with a price tag in excess of $1 million. Thomson Reuters subsequently adopted a two-tiered distribution arrangement to selectively release the ICS results to different groups of investors at different times on ICS announcement days.

The earliest wave of release happens at 9:54:48 a.m. Eastern Time, when Thomson Reuters sends out ICS numbers, in a specialized machine readable format, to a small group of

---

[10]For example, Brogaard, Hendershott, and Riordan (2012) studies the role of high-frequency trading in price discovery and shows some evidence that high-frequency traders contribute to price efficiency.

fee-paying, high-speed clients.[11] Two seconds later at 9:55:00, the ICS numbers are released in a conference call and also through all Thomson Reuters news terminals. At this point, other news providers such as Bloomberg also jump in to report the ICS results, making the index widely available to investors. Five minutes later at 10:00:00, the official numbers are posted on the website of University of Michigan Surveys of Consumers.

The availability of early access to the ICS results is not a secret in the high-frequency trading world. Thomson Reuters uses the ICS as the leading example in its marketing materials for the firm's low-latency news feed product, which releases more than 1200 economic indicators in formats specially designed for algorithm trading. This special arrangement only came in light after a series of front-page articles, which revealed the details of how an elite group of high-frequency traders, paying Thomson Reuters steep premiums, could gain early access at 9:54:58 and trade heavy volume two seconds ahead of the general public. The revelation sparked a widespread debate on how market-moving news, including those compiled by non-government entities, should be distributed to investors. Some argue that since the index is privately collected, the University of Michigan can distribute the index in whichever way they see fit. Others believe that this practice gives unfair advantage to a small group of high-frequency traders and therefore undermines the fairness of markets. On July 8, 2013, less than one month after the first news article broke out, Thomson Reuters suspended the selective disclosure practice, yielding to pressure from New York's attorney general, who is conducting an ongoing investigation into the distribution of economic sensitive data. From July 2013 on, ICS results are released to all Thomson Reuters regular subscribers at 9:55:00.

Before Thomson Reuters became the exclusive distributor of Michigan Surveys of Consumers in 2007, ICS was distributed to around 150 subscribers who paid an annual fee, in thousands of dollars, to the University of Michigan. The index subscribers, typically investment banks and broker dealers, obtained the first look at the ICS results at a conference call hosted by the University of Michigan. Measures were taken to ensure that all index

---

[11]According to a report by the New York Times on July 7 2013, *"Thomson Reuters to Suspend Early Peeks at Key Index"*, there are only around a dozen of high-frequency clients signed up for the ICS early release, each paying a fee of over $6,000 per month. The contract between Thomson Reuters and the University of Michigan allows a plus or minus 500 milliseconds error margin for the early release of ICS. On a very few occasions, high-speed traders could get the data as early as 9:54:57.500. Details are discussed in the section B of the appendix. Overall, our results are robust if we include 9:54:57 as part of the early peek window. But since early releases at 9:54:57 are not common, we use 9:54:48 and 9:54:59 as the 2-second early advantage window for our main results.

subscribers obtained the information at the same time.[12] But how the ICS numbers are distributed to non-subscribers is a gray area. Even though subscribers agree not to leak the information outside of their companies, the media routinely obtains the figures from subscribers soon after the announcement.

Because of the lack of documentation, we find few details on either the identities of these subscribers or the exact release time before 2007. The only public record from which we can identify the release time is Bloomberg, which covers the ICS announcements since May 1999 and records the time when it receives the ICS numbers from its sources. Bloomberg usually sends the results to its subscribers via Bloomberg terminals a few seconds after it receives the ICS numbers.[13] The ICS release time recorded by Bloomberg terminals can serve as an approximation of when ICS results were widely available to general investors before the Michigan-Reuters deal in 2007. The release time varies a lot before 2007, from as early as 9:35:00 to 10:00:00. From 1999 to early 2001 and from 2004 to 2006, the release time is usually either 10:00:00 or 9:45:00, with a few exceptions. From 2001 to the end of 2003, there is no clear pattern, except that most of the announcements are clustered around 9:46:00 to 9:50:00.

3 Data

3.1 ICS Announcements

ICS is released twice every month. The preliminary numbers, based on approximately 60% of consumers responses, are usually announced on the second Fridays of the month, and the revised final figures are typically announced on the fourth Fridays. We collect the release dates and ICS numbers from Bloomberg.

Table 1 is a summary of the ICS results from 1997 to 2013. We separate the sample into three periods: during, prior to, and post the early peek arrangement. The period with the early peek arrangement is from January 2008 to June 2013. We exclude 2007 from this

---

[12]When it was alleged that Market News International, a news website, published an article including the ICS numbers before the data was released to subscribers on February 13, 2004, the University of Michigan called for an investigation involving the Federal Bureau of Investigation and the Securities and Exchange Commission.

[13]We downloaded the ICS release time directly from the Bloomberg terminal. The details on how Bloomberg receives and distributes the ICS results are based on our own understanding through conversations with Bloomberg customer service representatives.

Table 1: **Summary Statistics for ICS**

	mean	std	Q1	median	Q3
Panel A: with early peek (Jan 2008 - June 2013)					
#Days	131				
ICS	69.6	7.3	63.8	70.6	74.2
△ICS	0.01	3.46	−1.1	0.5	1.9
Panel B: prior to early peek (Sep 1997 - Dec 2006)					
#Days	222				
ICS	95.4	9.3	88.4	94.1	104.8
△ICS	−0.04	2.98	−1.3	0.0	1.6
Panel C: post early peek (Jul 2013 - Oct 2013)					
#Days	7				
ICS	80.1	3.8	76.8	80.0	83.9
△ICS	−1.27	3.01	−5.1	−0.2	1.2

ICS is the Index of Consumer Sentiment compiled by the University of Michigan. △ICS is the change of ICS between two adjacent announcements. #Days is the number ICS announcement days (when the futures market is open). Q1 and Q3 are the values at the lower and upper 25%, respectively.

period because we cannot identify the exact date in 2007 when Reuters started to distribute ICS in multiple tiers.[14] For the sample period with the early peek arrangement, ICS was released 132 times, with one announcement on a non-trading day. So we end up with 131 announcement days in this sample period. Similarly, there are 224 ICS announcements during the period prior to the early peek deal, but we have only 222 days with trading information because two announcements happened on non-trading days.

During the early peak period, the average level of ICS is 69.6, which is around 26 points lower than the average level of 95.4 for the period prior to the early peak arrangement. This is a reflection of consumer pessimism since the 2007-2009 financial crisis. In terms of change of ICS, however, the numbers are comparable over the two sample periods. The mean and median of ΔICS are both close to zero in both sample periods. The standard deviation of ΔICS is 3.46 during the early peek period, compared with 2.98 for the prior period. The lower 25% value of ΔICS, which is labeled as Q1 in Table 1, is -1.j compared with -1.3 for the prior period. The upper 25% value of ΔICS, labeled as Q3, is 1.9, compared with 1.6 for the prior period. Overall, the degrees of variation in ICS are very similar in the two sample

---

[14]Our main results are robust whether we include or exclude year 2007 in our tests.

periods.[15] This indicates that there is no systematic shift in the informativeness of ICS announcements, and the only major difference between these two sample periods is how ICS news is released. For the post early peek period, we only have seven ICS announcements, making some of the statistics a bit sketchy and we intend to update the results for this period as more data becomes available.

3.2   E-mini S&P 500 Futures

Our main results are based on the trading of E-mini S&P 500 Futures. Because ICS is a reflection of the general economic condition, the natural place to trade on such information will be an instrument that is reflective of this condition. We choose E-mini S&P 500 Futures exactly for this reason. Compared with other cash instruments such as SPDR S&P 500 ETF, E-mini Futures is by far the more liquid instrument and is less affected by short-sale constraints.[16] We obtain the tick-by-tick transaction data of E-mini S&P 500 futures from the Chicago Mercantile Exchange (CME), which covers all the electronic trades on the Globex electronic trading platform since Sep 9, 1997. The trades are ordered by the sequence of their execution time, but are only time-stamped to seconds.

Table 2 provides the trading and pricing characteristics of E-mini S&P 500 futures. For each announcement day, we choose the most active futures contract with the highest volume, which is usually the nearest-term contract and occasionally the next contract during rolling forward weeks. To avoid contamination from any intra-day trading patterns, we report statistics only for transactions between 9:45:00 and 10:15:00, even though E-mini S&P 500 futures is traded almost around the clock. To provide a benchmark for normal conditions, we also collect a sample of non-ICS Fridays for each sample period and report the corresponding trading and pricing characteristics. Trading volume is reported in number of contracts, and the notional value of one E-mini S&P 500 futures contract is 50 times the S&P 500 stock index level. Return and volatility are measured in basis points.

When sampled over the half-hour window from 9:45:00 to 10:15:00, the one-second return volatility is on average 1.60 bps for the sample period with early peek, and there is no

---

[15]Another way to measure ICS surprises is using economists' forecast numbers as the benchmark for market expectations. We collect the forecast numbers surveyed by Bloomberg, and find that the median forecast numbers are usually coincide with the most recent ICS. The correlation of $\triangle$ICS and ICS surprises calculated using the median Bloomberg economists forecast is 0.97.

[16]The cash market results are reported in the appendix.

Table 2: **Summary Statistics of E-mini S&P 500 Futures**

variable	mean	std	Q1	med	Q3	mean	std	Q1	med	Q3
Panel A: with early peek (Jan 2008 - June 2013)										
ICS annoucement days (N= 131)						Non-ICS Fridays (N= 154)				
S&P 500 index	1220	204	1086	1257	1353	1218	205	1088	1252	1364
1sec return	0.00	0.02	−0.01	0.00	0.02	−0.00	0.03	−0.02	−0.00	0.01
1sec volatility	1.60	0.48	1.22	1.46	1.78	1.60	0.67	1.22	1.42	1.76
1min return	0.01	1.37	−0.70	0.00	0.84	−0.10	1.52	−0.81	−0.08	0.63
1min volatility	7.46	4.18	4.72	6.51	8.99	7.38	6.48	4.20	5.34	8.55
#trades	15.5	9.0	9.2	12.0	22.7	15.3	9.8	8.1	12.1	20.1
trade size	10.0	4.4	4.5	11.3	13.3	10.0	4.5	4.3	11.3	13.5
volume	123.8	43.1	99.5	119.8	143.0	122.5	57.8	90.0	115.6	142.7
Panel B: prior to early peek (Sep 1997 - Dec 2006)										
ICS annoucement days (N= 222)						Non-ICS Fridays (N= 269)				
S&P 500 index	1178	169	1072	1176	1306	1180	170	1066	1178	1308
1sec return	−0.01	0.03	−0.02	−0.01	0.01	−0.00	0.04	−0.02	−0.00	0.01
1sec volatility	1.72	0.54	1.35	1.58	1.96	1.64	0.53	1.31	1.48	1.80
1min return	−0.22	1.25	−0.96	−0.26	0.46	−0.06	1.34	−0.67	−0.07	0.56
1min volatility	6.47	2.97	4.38	5.75	7.77	6.06	2.81	4.05	5.57	7.24
#trades	2.7	1.7	1.2	2.7	3.9	2.6	1.7	1.1	2.6	3.6
trade size	8.5	6.3	3.0	6.4	13.0	8.7	6.3	3.1	6.7	13.7
volume	28.6	26.3	4.1	21.2	48.3	26.9	25.1	4.0	19.1	45.2
Panel C: post early peek (July 2013 - Oct 2013)										
ICS annoucement days (N= 7)						Non-ICS Fridays (N= 9)				
S&P 500 index	1670	19	1658	1679	1682	1679	36	1655	1681	1697
1sec return	−0.00	0.01	−0.01	−0.00	0.01	−0.00	0.01	−0.01	−0.01	0.00
1sec volatility	0.96	0.03	0.94	0.96	1.00	0.98	0.12	0.90	0.93	1.01
1min return	0.01	0.50	−0.48	−0.00	0.58	−0.15	0.80	−0.56	−0.34	0.14
1min volatility	3.80	0.51	3.45	3.69	4.33	4.08	1.62	3.10	3.32	4.18
#trades	21.9	3.8	17.7	22.0	25.4	29.7	16.3	21.1	27.3	28.4
trade size	3.7	0.2	3.6	3.6	3.8	3.7	0.5	3.3	3.6	3.9
volume	80.3	16.3	63.5	86.0	92.7	110.3	64.6	89.1	99.7	101.4

Transaction data of E-mini S&P 500 Futures are sampled from 9:45:00 to 10:15:00 am. Log-return and volatility are sampled at both one-second and one-minute frequency and reported in basis points. #trades is the number of trades per second. Trade size is the average number of contracts per trade. Volume is the total number of contracts traded per second. The reported statistics are the cross-day mean, std, median, Q1, and Q3 of daily averages. Q1 and Q3 are the value at the lower and upper 25%.

difference between ICS announcement days and non-ICS days. For the sample period prior to the early peek, however, the one-second return volatility is on average 1.72 bps on ICS announcement days, which is slightly higher than the one-second volatility of 1.64 bps on non-ICS days. This is an indication that the price adjustment to ICS announcements is so fast and short-lived that when sampled over the longer, half-hour window surrounding the announcements, the impact is no longer visible. This is especially true for the sample period with early peek arrangement.

For the sample period with early peek, the average one-second trading volume is 123.8 contracts on ICS announcement days and 122.5 contracts on non-ICS days. For the sample period prior to early peek, the average trading volume is 28.6 and 26.9 contracts per second, respectively. Not surprisingly, the announcement days attract higher trading volume, although the difference is rather small when sampled over the half-hour window. Moreover, the intensity of trading is very different for the two sample periods, which is a direct consequence of the increasing presence of high-frequency traders in the market over the years. Interestingly, for the sample period post early peek, the average one-second volume is 80.3 and 110.3, respectively, on ICS and non-ICS days.[17]

Overall, we do not see any large differences in trading and price behavior between ICS announcement days and non-ICS Fridays when the key variables are sampled over the half-hour window from 9:45:00 to 10:15:00. Comparing the sample period prior to early peek with the one with early peek, we do see an increasing presence of high-frequency traders in E-mini Futures. This is reflected in the substantial increase in the one-second trading volume and the number of trades. It is also reflected in the term-structure of high-frequency volatility: while the one-minute return volatility is lower during the early sample period, the one-second return volatility reverses the pattern and is higher during the early sample period. In other words, the increasing presence of high-frequency traders in the recent sample period smooths out the higher frequency returns and makes them less volatility.

---

[17]There are, however, only seven announcement days in the post early peek arrangement period.

4 Empirical Results

4.1 Abnormal Volume of Early Peek Trading

We first focus on the trading of E-mini S&P 500 futures during the two-second early peek window from 9:54:58.000 to 9:54:59.999 on ICS announcement days. For all ICS announcement days from September 1997 to October 2013, Figure 1 plots the time-series of $\triangle$ICS and the two-second trading volume and return of E-mini S&P 500 futures. From the middle panel, we see large spikes in two-second transaction volume during the early peek arrangement from January 2008 to June 2013, but very little abnormal trading prior to or post the early peek arrangement. By contrast, the top panel shows that $\triangle$ICS, which measures the information content of ICS, exhibits the same level of variations throughout the sample. So while the level of informativeness of ICS remains stable over time, the abnormally high trading volume over the two-second early peek window is only observed when the early peek arrangement is in place.

The intense trading during the two-second early peek window is accompanied with sizable price movement in E-mini S&P 500 futures. As demonstrated in the bottom panel of Figure 1, large two-second returns, in both positive and negative directions, are very common during the period with early release. Moreover, the correlation between ΔICS and the two-second early peek return is 0.67 during this sample period when the early peek arrangement is in place. By contrast, prior to the early peek arrangement, the two-second returns are not only small in magnitude but also have no correlation with $\triangle$ICS. Similarly, after the early peek arrangement was suspended at July 2013, large trading volume and returns disappeared, even though there were a few large negative $\triangle$ICS announcements during this period.

Putting together these evidences, there is very little double that the abnormally high trading volume during the early peek window comes from the trading of high-frequency traders who have advance access to ICS. It is also clear that information dissemination and price discovery with respect to ICS happens at 9:54:58 and 9:54:59 during the period when the early peek arrangement is in place. By contrast, there is no price discovery at those two seconds during the period prior to or post the early peek arrangement. It is also important to point out that although the sample period of early peek arrangement coincides with a relatively volatile period in the final markets, the large magnitudes of the two-second return at 9:54:58 and 9:54:59 on ICS announcement day is not a result of higher market volatility. For this sample period, the two-second volatility, sampled from 9:45 to 10:15, is on average
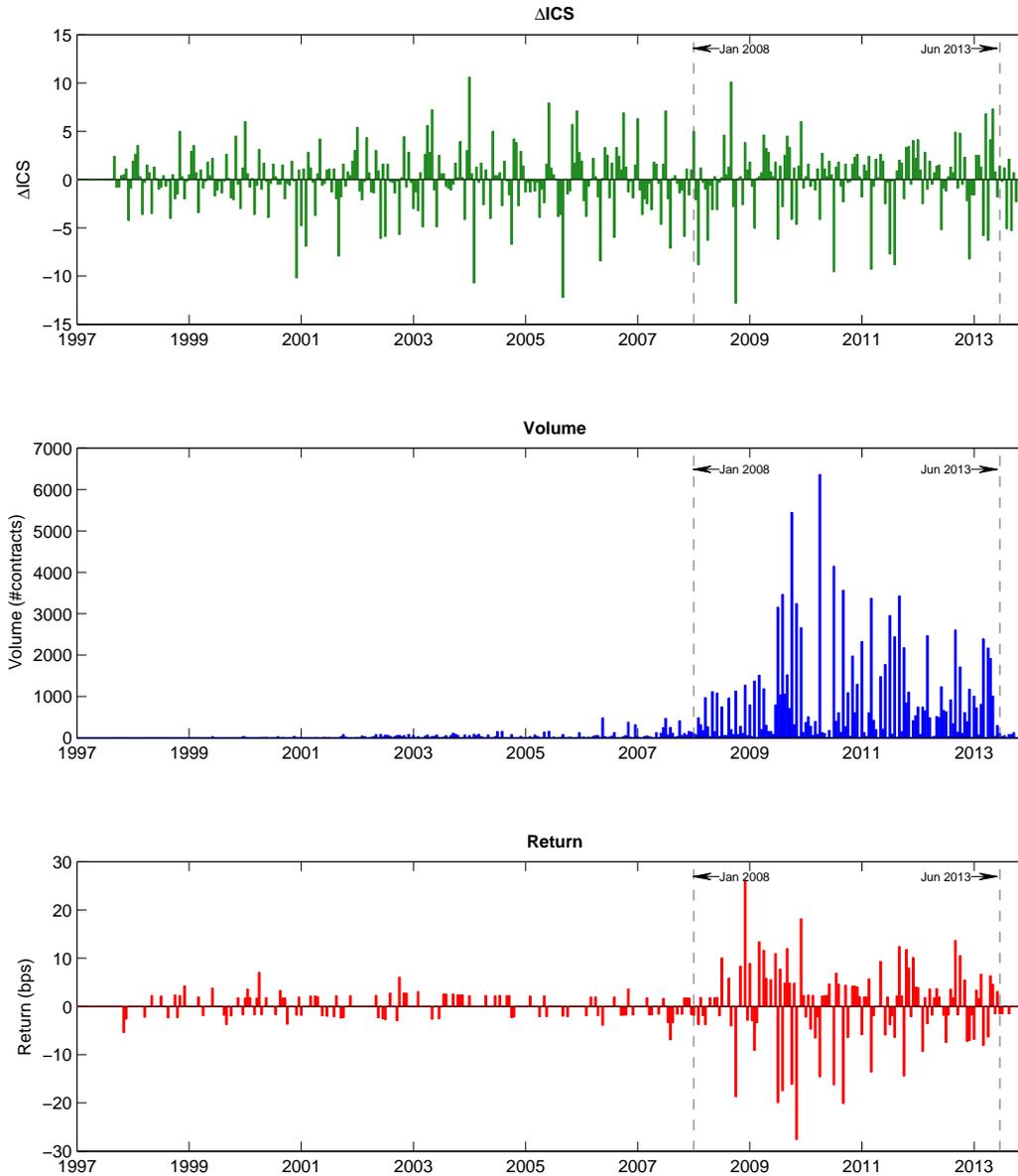
Figure 1: Time Series of $\triangle$ICS, two-second volume and return of E-mini S&P 500 at 9:54:58 and 9:54:59. $\triangle$ICS is the change of ICS between two adjacent announcements. Volume is two-second trading volume of E-mini S&P 500 futures measured in number of contracts, and return is the two-second log return of E-mini S&P 500 measured in basis points. Both volume and return are measured over the two-second interval at 9:54:48 and 9:54:59.

1.90 bps, with the lower and upper 25% values at 1.39 bps and 2.13 bps, respectively. By contrast, many of the two-second returns realized over those two-second early peek window are in the order of 10 basis points. Moreover, for the same sample period, we do not see such patterns of large two-second returns on non-ICS announcement days.

To further investigate the abnormal trading around the early peek window, Figure 2 plots second-by-second trading volume of E-mini S&P 500 futures from 9:50:00 to 10:15:00. The top panel is the average trading volume per second across the total 131 ICS announcement days from January 2008 to June 2013. For comparison, we also plot in the bottom panel the average trading volume of E-mini S&P 500 on non-ICS Fridays during the same sample period. The most striking observation is the huge spike up in trading volume, happening at exactly 9:54:58 on ICS announcement days. On average, there are 1,473 number of E-mini S&P 500 futures contracts exchanging hands during the single second of 9:54:58, around 12 times larger than the average trading volume of 124 contracts. The notional value for one E-mini S&P 500 futures contract is 50 times the S&P 500 index level, and the average level for S&P 500 during this period is around 1220. This roughly translates to a dollar trading volume of $90 millions per second at 9:54:58, much higher than the average $7.6 millions per second. In the following second at 9:54:59, the trading volume drops quickly to 261 contracts, still twice as large as the average one-second trading volume. In other words, even though a small group of informed high-speed traders had a full two seconds head start, they trade disproportionally in the first second of the early peek window.

After the broad release of ICS results at 9:55:00, the high trading volume of E-mini S&P 500 futures stays high but gradually dies out to the normal level in around two to three minutes. There is another spike in trading volume at 10:00:00. We do not believe this to be related to the ICS release on the University of Michigan's website at 10:00:00. Instead it is caused by trading in response to news announcements other than ICS. During our sample period, there are many other news regularly released at 10:00:00 on Fridays.[18] In fact, we see large trading volume at 10:00:00 on both ICS announcement days and non-ICS Fridays. Other than ICS, however, none of the other news is announced at 9:55:00 or 9:54:58, making it possible for us to use the non-ICS Fridays as the control sample to rule out effects not

---

[18]For example, Department of Labor released "Regional and State Employment and Unemployment" and "Usual Weekly Earnings of Wage and Salary Workers" at 10:00:00 on January 18, 2013, which is also an ICS announcement day. Another example is "monthly wholesale trade". The Department of Commerce releases them at 10:00:00 on Feb 8, 2013 and March 8, 2013, which are both Fridays but not ICS announcement days.
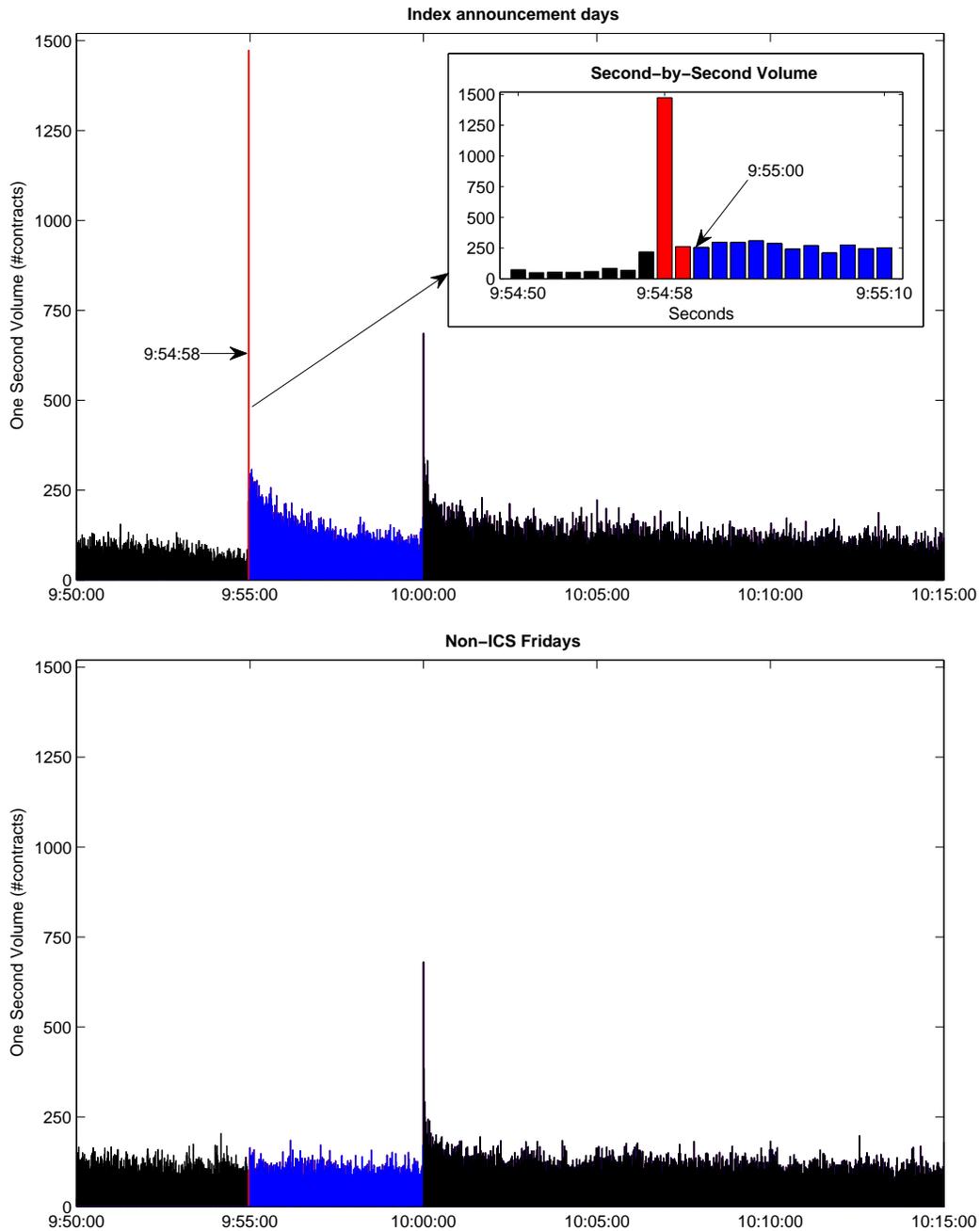
Figure 2: Second-by-second trading volume of E-mini S&P 500. We plot the average one second trading volume, in number of contracts, for E-mini S&P 500 from 9:50:00 to 10:15:00. The top panel is for ICS announcement days from January 2008 to June 2013 and the bottom panel is for non-ICS Fridays during the same period. The trading volume for 9:54:58 and 9:54:59 is in red and that from 9:55:00 to 9:59:59 is in blue.
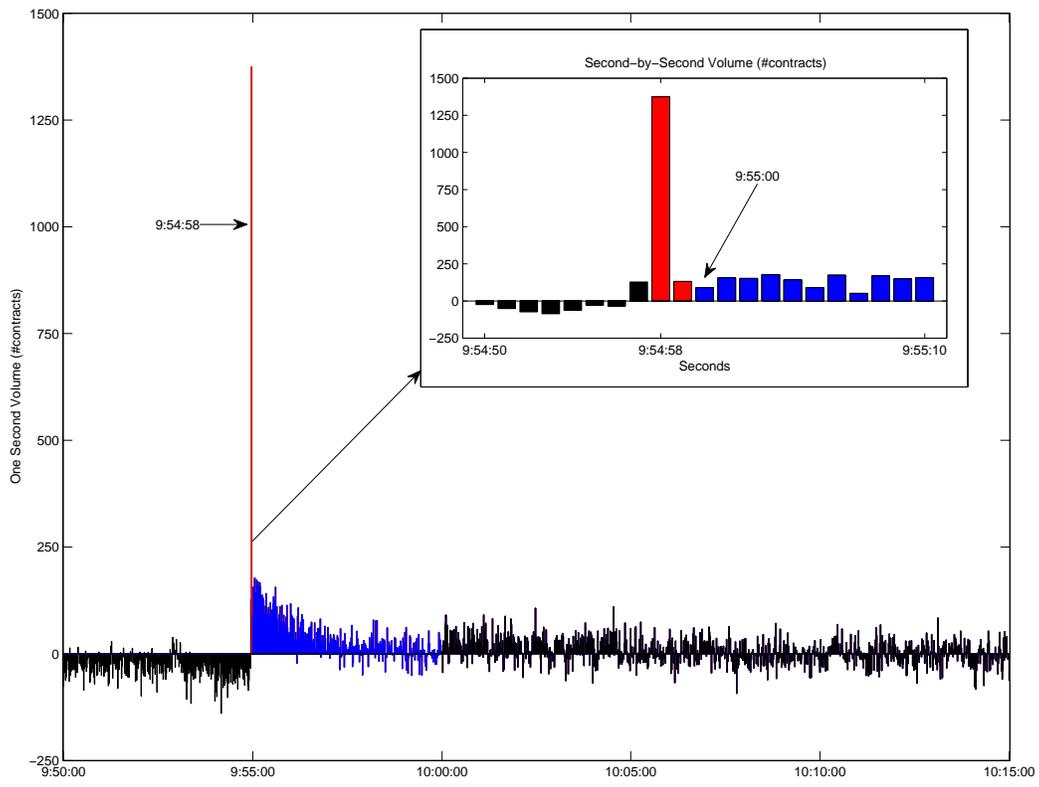
Figure 3: Time-series of average difference in second-by-second trading volume between ICS announcement and non-ICS Fridays during the early peek period from January 2008 to June 2013.

related to the ICS announcements.

Figure 3 plots the difference in second-by-second trading volume between ICS announcement and non-ICS Fridays. As expected, no large difference in transaction volume at 10:00:00 is observed. Moreover, the trading volume before 9:54:58 on ICS announcement days is generally lower than the average, suggesting that investors are waiting for the arrival of the new information and staying on the sidelines (see, for example, He and Wang (1995) and Chae (2005)). There is a small increase in transaction volume at 9:54:57, mainly because that Thomson Reuters clients can occasionally get the data as early as 9:54:57.500 due to the plus or minus 500 milliseconds margin of error in release time. Since the magnitude for the increase of trading volume at 9:54:57 is very small, we suspect that early release at 9:54:57 is not very common.

Overall, our analysis on the trading around the early peek window suggests that the coordinated trading by the informed high-speed traders is concentrated mostly during the first second of the early peek window. This highly concentrated and intense trading is very unique and can be clearly attributed to the early peek arrangement.

4.2 Price Discovery with Early Peek Trading

In order to examine the price impact of early peek trading, we fist need to identify the information content of ICS news. This can be done using the change in ICS from it previous release, the surprise component of ICS measured relative to economists forecast, or market's reaction to ICS release. We choose to use the last approach because we believe it to be a cleaner and sharper measure of information content embedded in ICS.[19]

We sort the ICS announcement days from January 2008 to June 2013 into three groups using the price movement of E-mini S&P 500 futures during the two-second early peek window. The two-second price movement is calculated as the last transaction price of E-mini S&P 500 futures during 9:54:59 minus the last transaction price during 9:54:57. Because the minimum tick size in E-mini S&P 500 futures is 0.25, we identify announcement days when price moves up by at least one tick and group them into the high group. Days when price moves down by at least one tick are grouped into the low group, and days with no

---

[19]Our goal is to group together announcement days with similar information content. As long as the sorting variable can capture the information content of ICS, our results should stay robust. We have tried alternative sorting variables such as $\triangle$ICS and the ICS surprises measured relative to Economists forecast numbers, and the results are very similar.

Table 3: **Return and volume for sorted groups on announcement days**

	Return			Volume				
	Low	Med	High	Low	Med	High	L-M	H-M
#Days	47	21	63					
△ICS	−2.35*** [−4.03]	−0.35 [−0.62]	1.90*** [8.52]					
9:54:58	−6.58*** [−7.39]	0.77* [1.77]	4.59*** [8.04]	2393	271	1195	2122*** [3.26]	924*** [3.01]
9:54:59	−0.49* [−1.90]	−0.70* [−1.76]	1.21*** [4.10]	319	162	263	157 [1.59]	101 [1.40]
9:55:00−9:55:59	−0.91 [−0.58]	2.65 [1.00]	−0.21 [−0.14]	256	182	196	75** [2.08]	14 [0.66]
9:56:00−9:56:59	−4.51*** [−2.61]	1.46 [0.53]	−0.14 [−0.11]	195	132	137	63** [2.36]	5 [0.30]
9:57:00−9:57:59	0.45 [0.39]	0.46 [0.25]	0.99 [1.23]	149	128	109	21 [0.92]	−20 [−1.55]
9:58:00−9:58:59	3.02** [2.02]	−3.82** [−2.15]	−0.71 [−0.66]	140	118	104	21 [0.95]	−14 [−0.74]
9:59:00−9:59:59	−1.16 [−0.78]	−1.45 [−0.70]	−0.13 [−0.17]	132	107	98	25 [1.29]	−9 [−0.69]
9:55:00−9:59:59	−3.12 [−0.93]	−0.70 [−0.15]	−0.21 [−0.10]	174	134	129	41** [2.16]	−5 [−0.42]
10:00:00−10:04:59	1.18 [0.52]	4.37 [0.79]	0.24 [0.09]	156	159	157	−3 [−0.15]	−2 [−0.07]
10:05:00−3:59:59	−8.54 [−0.79]	51.76** [2.14]	−5.13 [−0.44]	66	58	62	7 [1.27]	3 [0.58]
9:30:00−9:54:56	−3.27 [−0.48]	4.55 [0.55]	−0.16 [−0.04]	132	112	122	20** [2.23]	9 [1.05]
9:54:57	−0.37 [−0.66]	−0.75* [−1.81]	−0.04 [−0.11]	286	115	274	171 [1.26]	158 [1.27]

The sample period is from January 2008 to June 2013. ICS announcement days are grouped by E-mini S&P 500 price change during 9:54:58 and 9:54:59. The low (high) group contains announcement days when price moves down (up) by at least one tick during the early peek window, and the medium group contains announcement days with no price movement during the early peek window. Returns are log returns for the respective time interval and are in basis points. Volume is the number of contracts traded per second. "L-M" and "H-M" indicate the difference in volume between the low and medium group, and the high and medium group, respectively.

price movement are grouped into the medium group. Effectively, we are sorting the ICS information content into three groups based on the market reaction during the two-second early peek window.

As reported in Table 3, out of the 131 ICS announcement days, the market's reaction to the ICS news is negative on 47 days, positive on 63 days, and neutral on 21 days. On negative news days, $\triangle$ICS is on average -2.53 with a t-statistics of -4.03. On positive news days, $\triangle$ICS is on average 1.90 with a t-statistics of 8.52. On neutral news days, $\triangle$ICS is small in magnitude and statistically insignificant from zero. This indicates that the market's reaction during the two-second early peek is very much in line with $\triangle$ICS.

The one second return for 9:54:58 is on average -6.58 bps on negative news days and 4.59 bps on positive news days. Both numbers are strongly significant statistically. Given that the one-second return volatility is on average 1.60 bps for this sample period, these numbers are also large in economic significance. For the next second at 9:54:59, there is some additional price drift, with an average return of -0.49 bps one negative news days and 1.21 bps on positive news days. The magnitude, however, is much smaller, and their statistical significance is also much weaker. In other words, most of the price discovery happens in the first second of the early peek window, similar to our earlier observation that transaction volume is disproportionally concentrated at 9:54:58.

More importantly, there is no further price drift during the one minute after the broad release of ICS at 9:55:00. The average one-minute return from 9:55:00 to 9:55:59 is on average -0.91 bps on negative news days and -0.21 bps on positive news days. Neither number is statistically significant. Given that the one-minute return volatility during this sample period is on average 7.46 bps, these numbers are rather small in magnitude. This result indicates that the information content of the ICS index has been fully incorporated into the market price during the two-second trading within the early peek window. For (non-high-speed) investors without the early access, they are most likely trading at a market price that is fully adjusted to the ICS news and cannot profit from the news release at 9:55:00 (as long as they are not trading within the first 15 milliseconds). This group of investors indeed lose the opportunity to profit from trading on ICS announcements. But they are not disadvantaged by the informed high frequency traders in the sense that price discovery happens during the first 15 milliseconds of the early peek window through the trading amongst high frequency traders themselves. So as long as general investors stay out of the two-second early peek

window, they are not being picked off by informed traders.

After 9:56:00, there are further price fluctuations, as reported in Table 3 and Figure 4. In particular, on negative news days, the one-minute return from 9:56:00 to 9:56:59 is on average negative and significant. During the one-minute window from 9:58:00 to 9:58:59, it then reverses its negative drift and pulls the price back up. On both positive and neutral news days, there are also some visible swings in market price. We do not believe these price swings to be related to the early peek arrangement. By 9:55:00, ICS has already been widely available to all investors. Any price swings one minute after this broad release of information are equal opportunity for all investors. By then, the fee-paying, high-speed traders no longer have any information advantage over others.
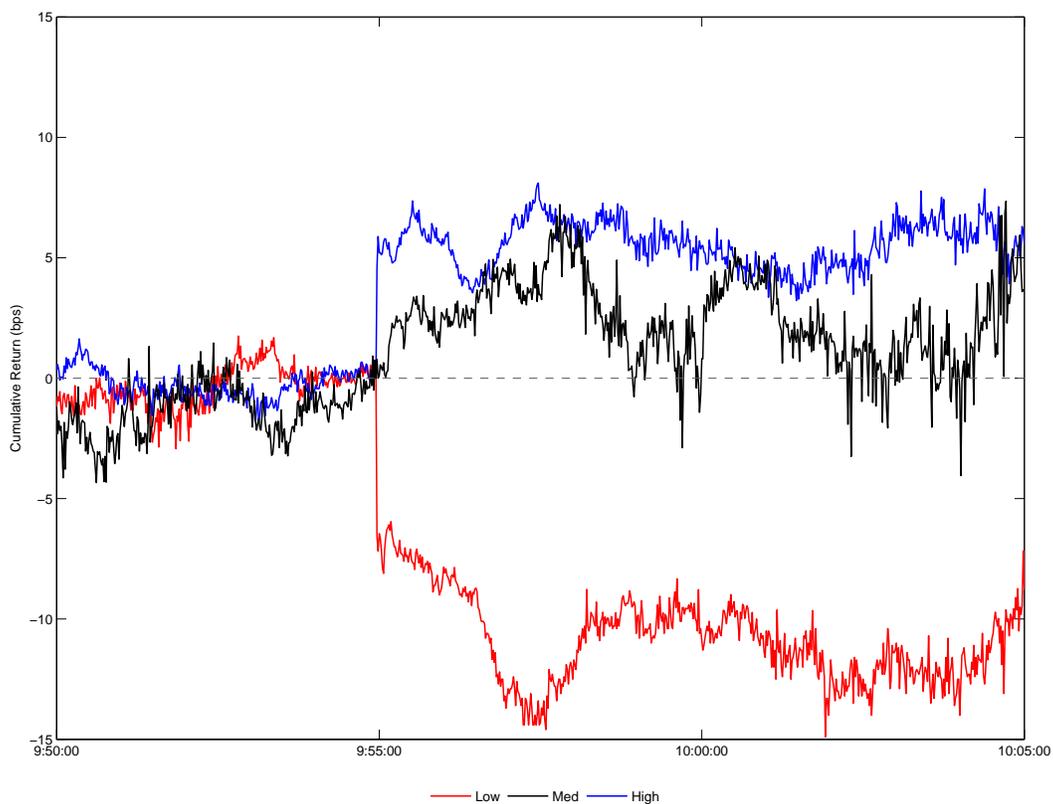

Figure 4: Cumulative returns for the low, med, high groups sorted by E-mini S&P 500 price movement during the 2-second early peek window. Cumulative returns are calculated relative to the end of 9:54:57.

For the trading window before the early peek window, from 9:30:00 to 9:54:56, there is no significant movement in prices, suggesting no leakage prior to the early peek window. The

return at 9:54:57 is also insignificant, implying that occasional early release at 9:54:57 is not common.[20]

Consistent with our earlier discussion on abnormal trading, high-frequency trading in the early peek window is mostly concentrated during the first second at 9:54:48. In Table 3, we see that the trading volume at 9:54:58 is on average 2393 contract per second on negative news days, 1195 contracts on positive announcement days, 271 contracts on neutral days. Not surprisingly, higher information content of ICS attracts more trading. Moreover, the effect is not symmetric, with negative news attracts more early peek trading. At 9:54:59, the trading volumes on the negative and positive news days are still at a high level, but are no longer statistically different from the trading volume on neutral days. In other words, while there are still abnormally high trading volume during 9:54:59 compared to the average volume, such trading is no longer informationally relevant.

The price and trading behavior surrounding the early peek window is further captured in Figure 5, which plots the average cumulative return and trading volume, second by second, for the three groups from 9:54:50 to 9:55:10. The cumulative returns are calculated relative to the end of 9:54:57, just before the early peek window. Consistent with our earlier discussion, the price discovery happens almost instantaneously during the first second of the early peek window at 9:54:58 and the trading volume is also concentrated around 9:54:58. It worth pointing out that, even on the neutral news day, when early peek trading does not result in any price discovery, we still see a trading volume at 9:54:58 that is twice as high as the average level and the difference is statistically significant.

4.3   Zoom in on Early Peek Window

Our analysis above shows that most of the early trading and the associated price impact happen during the first second of the early peek window at 9:54:58. We now take a closer look at the tick-by-tick transactions during 9:54:58. The futures transactions in our data, though only time-stamped to seconds, are in fact ordered by their physical transaction time. Taking advantage of this, we divide all trades during 9:54:58 equally into 10 intervals, in the order of their trade sequence. Interval 1 is therefore contains all trades that take place during the first 10% of the trades and interval 10 contains the last 10% of the trades in

---

[20]Issues related to occasional early release within the second 9:54:57 are discussed in the section B of the appendix.
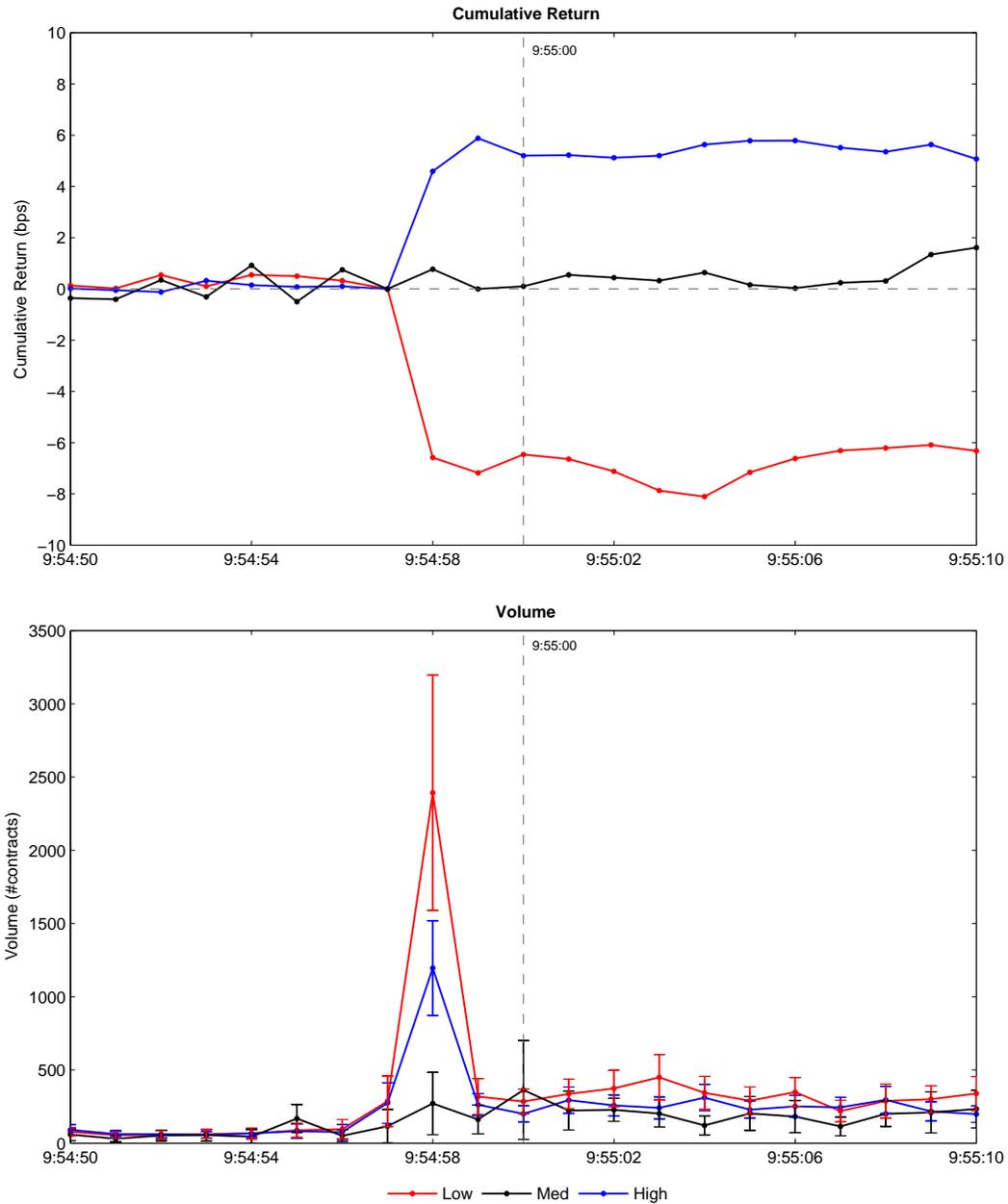
Figure 5: Cumulative return and volume around early peek announcement. Announcement days sorted into low, med, and high groups by E-mini S&P 500 price movement during the 2-second early peek window. The cumulative return is calculated relative to the end of 9:54:57 and is reported in basis points. The average one-second trading volumes, along with the 95% confidence intervals error bars, are in number of contracts.

9:54:58.

As reported in Table 4, the average return over the first 10% of the trades is -5.78 bps on negative news days. Compared with the average one-second return of -6.58 bps at 9:54:58 on negative news days, the first 10% of the trades during 9:54:58 accomplishes 88% of the one-second movement. Likewise, the average return over the first 10% of the trades is 4.20 bps on positive news days, accounting 92% of the total return in the full second. Figure 6 reports the same result. After the first 10% of the trades, there is barely any further price movement during the first second of early peek window. Moreover, trading activity is also overwhelmingly clustered around the first 10% of the trades. On negative news days, associated with the first 10% of the trades is a total trading volume of 1,147 contracts, which accounts for 48% of the total trading volume of 2393 contracts during the entire second at 9:54:58. Similarly, on positive news days, the first 10% of the trades has a total volume of 469 contracts, which is 39% of the one-second trading volume of 1195 contracts at 9:54:58. Even for news days when ICS does not have any informational content, the first 10% of the trades has a total volume of 137 contracts, which is 51% of the one-second trading volume of 271 contracts at 9:54:58.

Overall, these numbers paint a picture of highly intense and concentrated trading involving mostly fee-paying, high-speed investors. With such coordinated trading, price discovery is super fast. With the first 10% of the trades at 9:54:58, most of the information in ICS has already been priced into the market. The scope of information advantage enjoyed by such fee-paying, high-speed traders is therefore very limited. Moreover, not all trading during the early peek window is information driven. In particular, the remaining 90% of the trades barely moves the price. Yet, they still account for about 50% of the trading volume during 9:54:58. In other words, among the highly intense trading among fee-paying, high-speed traders at 9:54:58, only the fastest trades can potentially profit from the early peek advantage while the slower trades during the early peek window are traded at the adjusted market prices and do not enjoy any information advantage. In other words, a large component of the early peek trading is in fact not information driven. Instead, they might be driven by rebalancing needs, either to unwind existing positions built before the early peek window or to adjust positions in response to the new price level.

To further calibrate the first 10% of the trades to physical time, we take advantage of a private dataset, which contains E-mini S&P 500 transactions from March 2012 to June 2013

Table 4: **Trades within the second of 9:54:58**

Trade Sequence Intervals	Return			Volume					Milliseconds*		
	Low	Med	High	Low	Med	High	L-M	H-M	Low	Med	High
1	−5.78*** [−7.01]	−0.19 [−1.00]	4.20*** [7.65]	1147	137	469	1010** [2.24]	332 [1.23]	15	14	16
2	−1.45*** [−3.51]	−0.01 [−0.03]	0.33 [1.27]	349	57	138	292** [1.99]	81 [1.62]	41	17	33
3	0.23 [0.47]	−0.36 [−1.47]	0.10 [0.42]	300	31	97	269 [1.09]	67* [1.79]	103	26	67
4	−0.15 [−0.35]	−0.13 [−0.43]	0.73** [2.25]	164	39	161	126** [2.58]	122 [1.48]	124	61	76
5	−0.70* [−1.81]	0.39* [1.82]	0.10 [0.37]	136	22	87	114*** [3.29]	65** [2.40]	192	104	120
6	0.39* [1.82]	0.32 [0.73]	−0.22 [−0.98]	181	38	91	143** [2.44]	53 [1.53]	187	170	187
7	−0.13 [−0.52]	0.05 [0.15]	−0.16 [−0.67]	153	24	86	129** [2.22]	61*** [2.63]	257	189	240
8	−0.29 [−0.99]	0.25 [0.79]	0.35 [1.38]	141	25	88	116*** [2.78]	63** [2.16]	389	352	344
9	−0.06 [−0.20]	−0.45 [−1.06]	0.26 [0.86]	140	15	79	125*** [2.98]	64** [2.52]	469	504	485
10	−0.10 [−0.36]	0.79** [2.47]	−0.24 [−1.04]	131	13	75	118*** [3.82]	61*** [2.74]	683	601	715

Trades within the second of 9:54:58 are equally divided into 10 intervals, based on the order of their transaction time. The average transaction time for trades in each interval, measured in milliseconds, is calibrated using a shorter sample of data from March 2012 to June 2013.
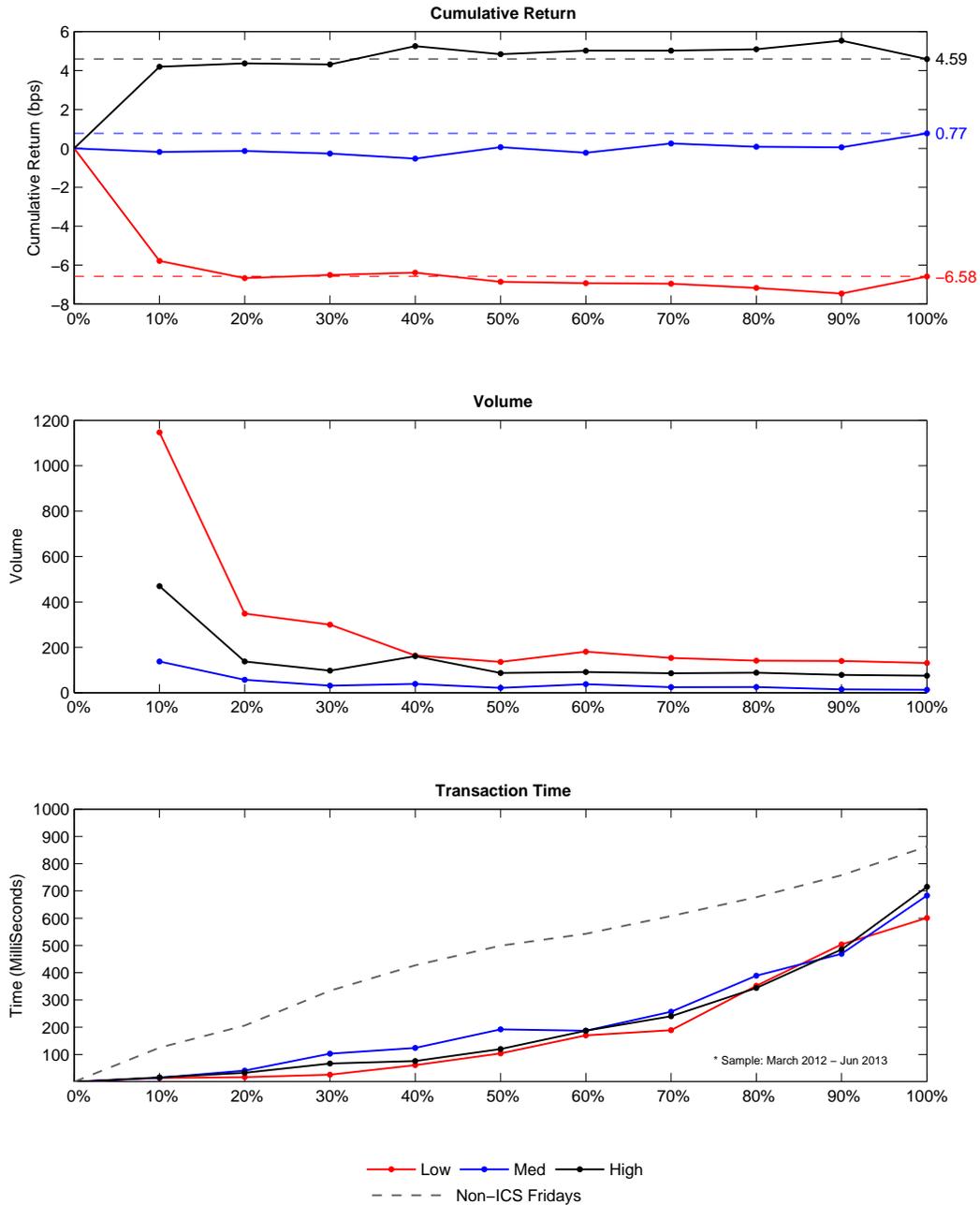
Figure 6: Cumulative return, volume and transaction time for trades within the second of 9:54:58. Announcement days sorted into low, med, and high groups by E-mini S&P 500 price movement during the 2-second early peek window. Trades within the second of 9:54:58 are equally divided into 10 intervals, by the sequence of their transaction time. The transaction time measured in milliseconds are calibrated using a subsample of data from March 2012 to June 2013.

with millisecond time stamps. As reported in Table 4, the first 10% of the trades during 9:54:58 takes place around 14 to 16 milliseconds on ICS announcement days. By contrast, on non-ICS Fridays, the first 10% of the trades during 9:54:58 takes place around 125 milliseconds. Moreover, as plotted in Figure 6, the rest 90% of the trades on announcement days are more likely to be clustered around the earlier part of 9:54:58, while trades on non-news Fridays are distributed more evenly across the full second. The relative short duration for trades within the second 9:54:58, especially for those in the top 10%, underscores the rapid-fire buying and selling of sophisticated high-frequency algorithms which are specially programmed to trade on market moving news.

To look even more closely to the actual transaction data, we plot in Figure 7 tick-by-tick transactions for a few ICS announcement days. From March 2012 and June 2013, when we have access to E-mini Futures data with millisecond time stamps, we pick six ICS announcement days and plot the tick-by-tick E-mini S&P 500 futures transactions with respect to their milliseconds transaction time from 9:54:56 to 9:55:00. The top two panels in Figure 7 plot the transactions on two announcement days with the highest $\triangle$ICS over this subsample: $\triangle$ICS is 7.3 on May 17, 2013 and 4.9 on Sep 14, 2012. The ICS numbers for these two days indicate that consumer confidence improves substantially, and should be considered as good news for the market. Indeed, there is intense trading and large price movement after the early release of ICS number. Most interestingly, the spikes in trading volume and the big jump in price both happen almost instantly around 9:54:58. For transactions occurred later, they are smaller in sizes and do not seem to move prices.

Trading and price patterns are similar for ICS announcement days with large negative news. The bottom two panels of Figure 7 focus on the two announcement days with the most negative $\triangle$ICS during the subsample period. We observe that transactions with large trading volume move future prices down immediately after the ICS releases. By contrast, when there is no surprise in ICS, transaction volume is lower and prices stay stable. The middle two panels plot the two days in the subsample period when $|\triangle$ICS$|$ is the smallest. On both days, trading is very thin and prices move back and forth in a range of one tick size, likely due to the bid ask bounce.
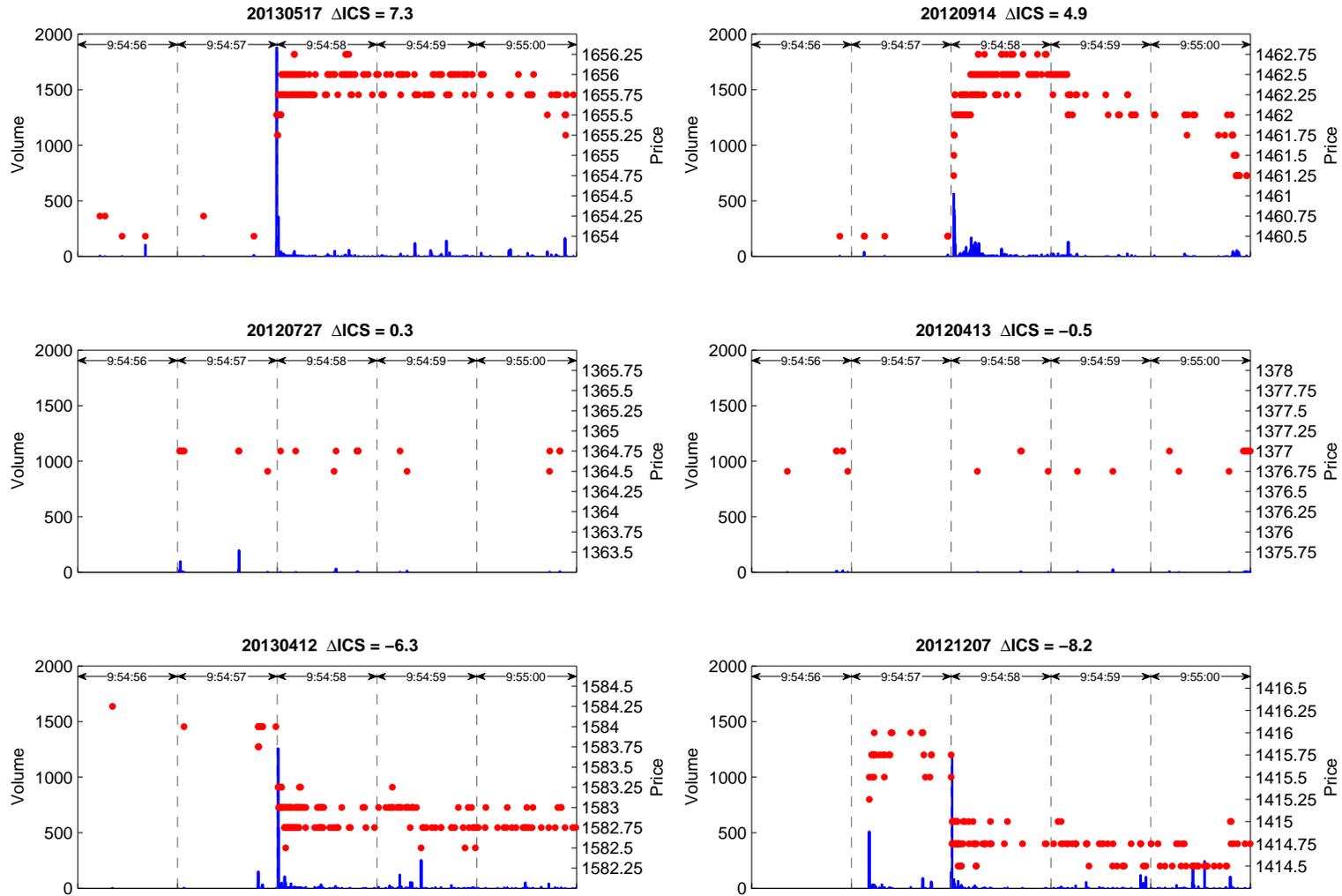
Figure 7: Trades around the 2-second early peek window. We plot the tick-by-tic transactions of E-mini S&P 500 from 9:54:56 to 9:55:00. The horizontal axis is transaction time in milliseconds. The blue bars are volume for each transaction, measured as number of contracts. The red dots are transaction prices.

4.4 Price Discovery without Early Peek Trading

While the highly concentrated and intense trading can be uniquely attributed to the early peek arrangement, it is not clear whether or not the super fast price discovery is the result of the early peek arrangement. To obtain a better understanding of how such mechanism of tiered information release can help or hurt price discovery, we turn to the two sample periods without the early peek arrangement.

The period prior to early peek arrangement is not ideal for us for two reasons. First, the presence of high-speed trading varies significantly over time from 1997 to 2006. In fact, the early peek arrangement by Thomson Reuters is to some extent a response to the increasing presence of high-speed trading. As a result, the speed of price discovery could be rather different over these two samples even without the early peek mechanism. Second, we cannot identify the exact time when the University of Michigan released the ICS results to its subscribers prior to the early peek arrangement. As discussed in the Data section, even the release time to the general public is difficult for us to pin down for this sample period.

The period after the early peek arrangement, however, is ideal for our investigation. The trigger was abrupt and purely exogenous. Moreover, there is no dramatic variation in terms of high-frequency activity during those two sample periods. Unfortunately, we have an extremely short sample for the post period with only seven ICS announcements since July 2013.

In Table 5, we investigate the sample period post early peek arrangement. Panel A establishes a benchmark using the period with early peek arrangement. Again, the low, medium, and high group contains announcement days sorted by price movement during the two-second early peek window at 9:54:58 and 9:54:59. For the post period, there is no early peek and general investors receive the ICS result at exactly the same time at 9:55:00.[21] For this reason, we sort announcement days by price movement during the two-second window of 9:55:00 and 9:55:01. For the seven ICS announcements after July 2013, E-mini Futures price moves down by at least one tick during this two-second window on two announcement days and stays the same for the rest five announcement days. There is no announcement day when E-mini Futures price move up during 9:55:00 and 9:55:01.

Given the limited data, especially the two data points for the low group, it is difficult to

---

[21] At 9:55:00 when Thomson Reuters releases the ICS results to its regular subscribers, other news agencies also jump in to report the numbers. As a result, the ICS numbers are widely reported and available to many investors at 9:55:00.

Table 5: **Price Discovery with and without Early Peek**

Period	Return			Volume		
	Low	Med	High	Low	Med	High
Panel A: with early peek (Jan 2008 to June 2013)						
# Days	47	21	63			
△ICS	−2.35*** [−4.03]	−0.35 [−0.62]	1.90*** [8.52]			
9:54:58 − 9:54:59	−7.06*** [−7.65]	−0.00 [−1.21]	5.76*** [9.90]	1353	204	725
9:55:00 − 9:55:01	0.42 [1.17]	0.55 [0.62]	−0.60* [−1.72]	311	293	246
9:55:02 − 9:55:10	0.55 [0.80]	0.81 [0.65]	0.46 [0.63]	326	178	250
9:55:11 − 9:55:59	−1.88 [−1.35]	1.28 [0.57]	−0.09 [−0.06]	243	178	185
Panel B: post early peek (July 2013 to Oct 2013)						
# Days	2	5	0			
△ICS	−5.20	0.30 [0.40]				
9:54:58 − 9:54:59	0.00	−0.60 [−1.63]		47	54	
9:55:00 − 9:55:01	−3.01	−0.00 [−0.32]		372	20	
9:55:02 − 9:55:10	−2.23	0.01 [0.02]		87	59	
9:55:11 − 9:55:59	−4.48	−0.31 [−0.20]		128	67	

Panel A is for the period with the early peek arrangement, the low, med, and high groups are the same as those in Table 3. Panel B is for the period post the early peek arrangement. ICS announcement days are sorted into low, medium, and high groups by E-mini S&P 500 price movement during the two-second of 9:55:00 and 9:55:01. The low (high) group contains ICS announcement days when price moves down (up) by at least one tick, and the med group contains ICS announcement days when price does not move.

discuss the number in terms of statistical significance. Instead, we gauge the price impact by judging the numbers by their economic significance. For this, we establish some benchmark numbers using the summary statistics reported in Table 2 for this sample period. From July 2013 to October 2013, when sampled over the half-hour window from 9:45 to 10:15, the average trading volume is 80 contracts per second on ICS announcement days and 110 contracts per second on non-ICS Fridays. The one-second volatility is 0.96 bps on ICS announcement days and 0.98 on non-ICS Fridays. The one-minute volatility is 3.80 bps on ICS announcement days and 4.08 on non-ICS Fridays.

Using these benchmark numbers, we can make the following observation. First, post early peek, there is no abnormally high trading during the two seconds of 9:54:58 and 9:54:59. The trading volume is 47 and 54 contracts per second, respectively, on low and medium days. Compared with the sample average, these trading volumes are much lower, indicating that investors are staying on the sidelines prior to a scheduled news release. Second, over the two seconds of 9:55:00 and 9:55:01, right after the news release, the trading volume is 372 contract per second on the two negative news days, much higher than the average trading volume. By contrast, the trading volume on the five neutral days is on average only 20 contracts per second. Indeed, when the ICS news has information content, there is higher than average trading right after its release. The trading intensity of 372 contracts per second, however, is no comparison to the trading intensity during the early peek period, when the trading volume over the two-second early peek window is 1353 contracts per second on negative news days. Third, the price adjustment over the two-second of news release is on average -3.01 bps on the two negative news day. Compared with the two-second volatility of 1.08 bps for this sample period, this return on negative news day is important economically. Moreover, the average $\triangle$ICS is on average -5.20 on those two negative news days, confirming that these are indeed days with disappointing ICS announcements.

More interesting and important for us is the price behavior after the first instance of news release. In particular, is there a post announcement drift? From our earlier investigation of the period with early peek arrangement, we see a pattern of super fast price discovery with no further price drift during the one-minute window after 9:55:00 when the early peek trading closes. In Table 5, we further cut this minute into three intervals. On negative news days, the average two-second return from 9:55:00 to 9:55:01 is 0.42 bps, the average nine-second return from 9:55:02 to 9:55:10 is 0.55 bps, and the average 49-second return from

9:55:11 to 9:55:59 is -1.88 bps. None of these numbers are statistically significant.

For the post early peek period, however, we see a different picture. From 9:55:02 to 9:55:10, immediately after initial two-second window of news release, the average return on the two negative news days remains negative at -2.23 bps. Compared with the 9-second volatility of 1.72 bps during this sample period, this further drift remains economically large. For the next 49 seconds from 9:55:11 to 9:55:59, price further drifted in the same direction with a return of -4.48 bps. Compared with the one-minute volatility of 3.80 one ICS announcement days during this sample period, this further drift remains economically important.

The important difference in trading activity and price discovery can be further illustrated by Figure 8. The left hand panels are for the period with the early peek arrangement, while the right hand panels are for the period post the early peek arrangement. Not surprisingly, since the suspension of the early peek arrangement, abnormal trading at 9:54:58 and 9:54:59 has shifted to 9:55:00, when ICS news is released to investors. But the magnitude of the abnormal trading volume is much smaller now that the early peek arrangement has been suspended. Associated with this less intense trading environment is a much slower price discovery. Comparing the two top panels, we see that on negative ICS news days, the information content of ICS news is comparable: the one-minute cumulative return after ICS release is -8.86 bps and -9.72 bps, respectively, before and after the suspension of the early peek arrangement. With the early peek arrangement, this information takes less than a second to get impounded into the price. Without the early peek arrangement, however, there is a persistent price drift after the news release and the speed of price discovery is much slower.

With a very limited sample such as this, the results for the post early peek period is perhaps not fully convincing. But the general pattern emerged from our very preliminary investigate is that, without the highly intense and concentrated trading induced by the early peek mechanism, trading of the ICS news is more dispersed over time and there is more of a drift after the scheduled news release and price takes longer to adjust to the information content of ICS. We plan to revisit this section after more data becomes available.
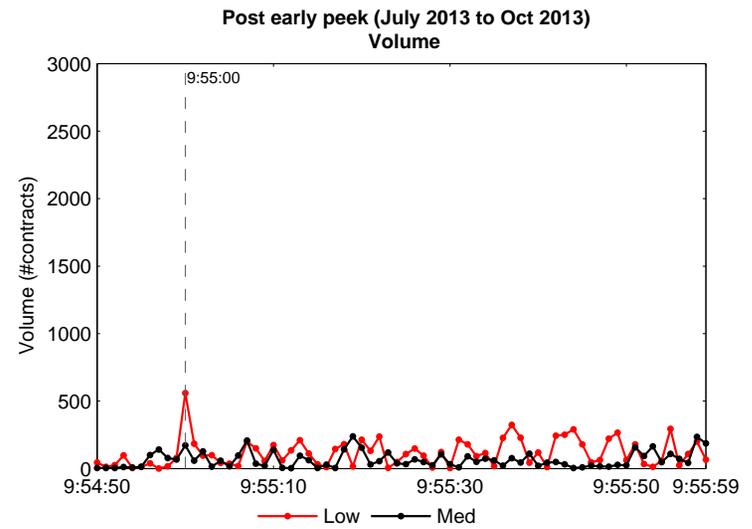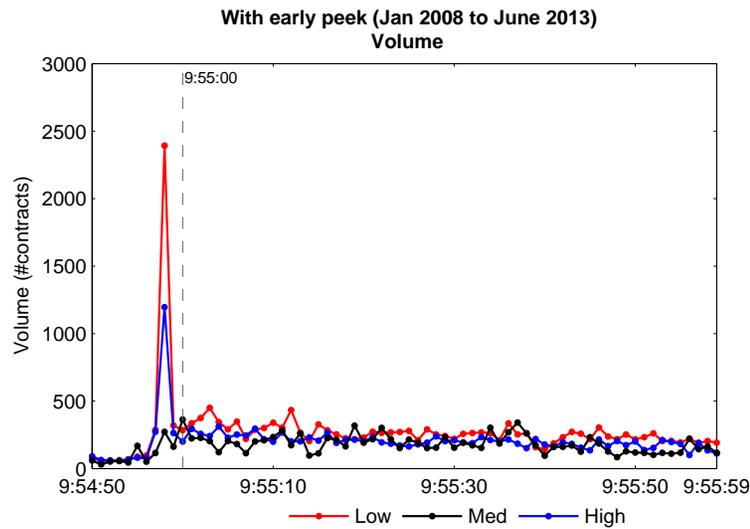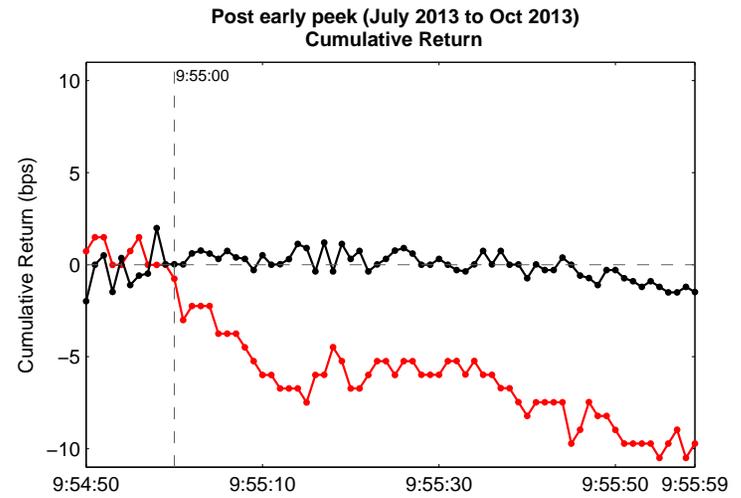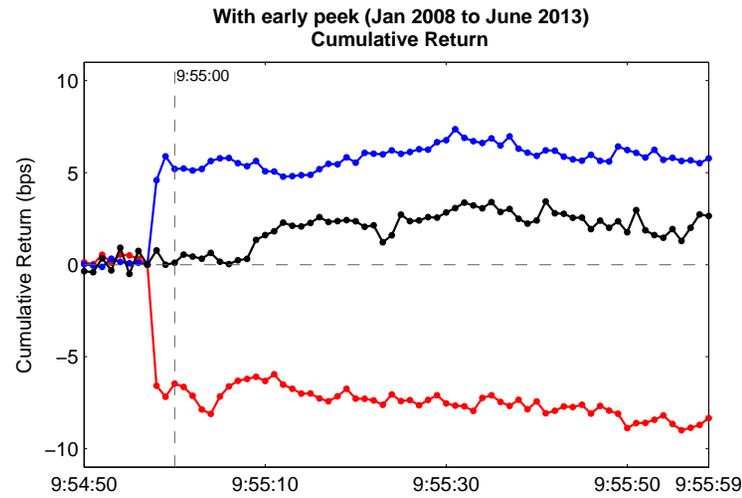
Figure 8: The left panels are for the period with the early peek arrangement, while the right panels are for the period post the early peek arrangement. For the left panels, ICS announcement days are grouped by E-mini S&P 500 price change during 9:54:58 and 9:54:59, and the cumulative return is calculated relative to the end of 9:54:57. For the right panels, ICS announcement days are grouped by E-mini S&P 500 price change during 9:55:00 and 9:55:01, and the cumulative return is calculated relative to the end of 9:54:59. In both panels, the cumulative return is reported in basis points and the average one-second trading volumes are in number of contracts. The time window is from 9:54:50 to 9:55:59.

5 Conclusions

In this paper, we study the trading and price behavior in E-mini S&P 500 futures when a group of high-speed traders have advance access to the index of consumer sentiment two seconds before its general release. We find that high-speed traders trade heavily on their early peek information, especially during the first second at 9:54:58. During this single second, there are, on average, 1473 E-mini S&P 500 futures contracts exchanging hands, more than 12 times larger than the normal trading volume. This concentrated and coordinated trading by high-speed traders leads to super fast price discovery. In approximately 15 milliseconds, most of the information content of ICS has already been priced into the market. After this short window, there is no further price drift in the remaining time of the early peek window and of course afterwards, including the public announcement at 9:55:00.

Our findings show that the price discovery for ICS is accomplished in the very beginning of the second 9:54:58 and involves mostly high-frequency traders who paid for the early peek information. For general investors without the early access, they won't profit from the public release of ICS two seconds later at 9:55:00 because they will face fully adjusted market prices. However, as long as general investors don't trade at the first 15 milliseconds when the price discovery takes place, which is very often the case, they are not disadvantaged by the informed high-frequency traders. For the short sample after the suspension of the early release, we find that trading becomes more dispersed and the information content of ICS takes longer to be priced into the futures market.

Appendix

A Early Peek Trading in Cash Markets

In addition to the futures market we focus in this paper, high-frequency traders can also trade in the cash and options markets based on their advance information. Examples include the SPDR S&P 500 ETF, Consumer Discretionary Select Sector SPDR and S&P 500 Index Options etc. In this section, we investigate early peek trading in the cash market, in particular the SPDR S&P 500 ETF (SPY). We find very similar results as those in the futures market. That is: early trading in the cash market concentrates in the first second 9:54:48; market prices move fast to reflect the new ICS information; and there is no further drift in prices after the early peek window.

Table AI summarizes the trading characteristics for SPY, based on transactions between 9:45:00 and 10:15:00 during the early peek period from January 2008 to June 2013. The one-second return volatility is on average 1.26 bps for the 131 ICS announcement days, compared with 1.20 bps for the 154 non-ICS announcement days. The turnover are, on average, 0.19 bps and 0.18 bps for ICS and non-ICS days. These numbers suggest that announcement days attract higher trading and have more volatile prices, the differences, however, are rather small when sampled over the half-hour window around the ICS release time.

Table AII reports the trading and the associated price impact in SPY. The ICS announcement days in the low, med and high groups are the same 47 negative, 21 neutral and 63 positive ICS news days that we use in our main results. We choose to use the same groups of ICS announcement days so that the cash market results are on an equal footing with the futures market results, with differences can only be driven by specifics in the cash market and not by information content of ICS itself. There are of course multiple alternative approaches, including sorting directly on cash market's reaction to ICS release. Our results stay robust, as long as the sorting variable captures the information content of ICS.

As reported in table AII, a big chunk of the early trading concentrates in 9:54:58. The average one second turnover are 2.65 bps and 2.17 bps for the negative and positive news days, well above the average 0.43 bps turnover on the neutral news days and the average 0.19 bps turnover when sampled across the half-hour trading window from 9:45:00 to 10:15:00 on all ICS announcement days. For the next second 9:54:59, the negative and positive news

Table AI: **Summary Statistics for SPDR S&P 500 ETF**

variable	mean	std	Q1	median	Q3	mean	std	Q1	median	Q3
	Sample period with early peek (Jan 2008 - June 2013)									
	ICS annoucement days (N= 131)					Non-ICS Fridays (N= 154)				
1sec return	0.00	0.02	−0.01	0.00	0.02	−0.00	0.03	−0.02	−0.00	0.01
1sec volatility	1.26	0.71	0.79	1.07	1.46	1.20	0.89	0.73	0.93	1.38
1min return	0.03	1.39	−0.67	0.03	0.81	−0.11	1.51	−0.84	−0.08	0.68
1min volatility	7.42	4.34	4.34	6.14	9.13	7.14	6.40	3.97	5.24	8.58
#trades	35.1	17.0	22.6	31.3	43.3	33.0	21.1	19.1	28.2	38.0
trade size	0.39	0.09	0.33	0.36	0.40	0.38	0.07	0.34	0.37	0.41
volume	13.24	6.19	8.85	12.41	16.36	12.51	8.19	7.58	10.18	14.64
turnover	0.19	0.11	0.12	0.17	0.24	0.18	0.12	0.11	0.15	0.20
bid/ask	1.50	0.54	1.14	1.31	1.72	1.42	0.59	1.06	1.25	1.56

Transaction data of SPDR S&P 500 (SPY) are sampled from 9:45:00 to 10:15:00 am. Log-return and volatility are sampled at both one-second and one-minute frequency and reported in basis points. #trades is the number of transactions per second. Trade size is the average number of shares per trade. Volume is the total number of shares traded per second. Turnover is volume divided by total number of shares outstanding. Bid/ask is the differences between bid and ask prices, scaled by the mid price. #trades, trade size, volume are reported in thousands. Turnover and bid/ask are reported in basis points. The reported statistics are the cross-day mean, std, median, Q1, and Q3 of daily averages. Q1 and Q3 are the value at the lower and upper 25%.

days still attract higher trading than the neutral news days, but the magnitudes of turnover have dropped sharply to 0.90 bps and 0.57 bps. The turnover for the neutral news days is reduced to 0.16 bps, close to the average level of turnover.

In terms of price discovery, most of the actions takes place at 9:54:58. The one second return of SPY for the negative and positive news days are -4.78 bps and 4.24 bps, close and slightly smaller compared with the return of E-mini S&P 500 futures in the futures market. Return on the negative news days have an additional -1.08 bps drift in the next second, while return on the positive news days don't drift any further. SPY prices don't move significantly on the neutral news days. Following the public release of ICS at 9:55:00, there is no significant further price adjustment across all three groups. Prior to the early peek, the return at 9:54:57 is -0.88 bps for the negative news days and 0.53 bps for the positive news days, small but statistically significant. We think this is due to occasional early release at 9:54:57 since we also observe a small pick up in turnover, 0.33 bps for the negative and 0.39 bps for the positive news days. However, we want to emphasize that their economic significance is weak comparing with the 1-second volatility of 1.26 bps and the bid/ask spreads of 1.5 bps.

To summarize, we find early trading and the associated price behavior in the cash market are very similar to those in the futures market. Most importantly, we confirm that the ICS information is also fully priced in the cash market through early trading by fee-paying high-speed traders, and there is no further price adjustment after ICS information is announced to public at 9:55:00. To understand better the dynamics between the cash market and the futures market, especially around the early peek window, we perform a battery of lead-lag analysis for the returns in these two markets. The results are summarized in Table AIII.

In the panel A of table AIII, we test whether ϵ_{58}^{ES}, the residual term of the futures return at 9:54:58 in the regression $R_{58}^{ES} \sim R_{58}^{SPY} + \epsilon_{58}^{ES}$, can predict cash market return at 9:54:59 (R_{59}^{SPY}) and at 9:55:00 (R_{00}^{SPY}). We use the orthogonal term of the futures return to avoid any potential multicollinearity due to the contemporaneous correlation between the futures and cash markets. Likewise, we also test the reverse causality: whether ϵ_{58}^{SPY}, the orthogonal term of cash return at 9:54:58, can predict the futures return at 9:54:59 (R_{59}^{ES}) and at 9:55:00 (R_{00}^{ES}). In the panel B of the table AIII, we test the predictive power of return at 9:54:59 for the return in the next two seconds, 9:55:00 and 9:55:01.

We find strong evidence that the futures market leads the cash market, and no evidence that the cash market can predict the futures market during the early peek window. The futures market return at 9:54:58 (ϵ_{58}^{ES}) can significantly explain the cash market return at 9:54:59 (R_{59}^{SPY}) with an adjusted R-squared 35.5% on ICS announcement days. The loading on ϵ_{58}^{ES} is 0.387 with a significant t-statistics of 2.55. In the next second 9:54:59, the futures market still leads the cash market by one second, but only marginal significant with a t-statistics of 1.92. The predictive power of the futures market for the cash market is only significant at 1 second horizon. The futures return at 9:54:58 can't predict the cash market return two seconds later at 9:55:00 and the futures return at 9:54:59 can't predict the cash market return two seconds later at 9:55:01. Interestingly, the cash market has no predictive power for the futures market, in neither 1-second nor 2-second horizon. We perform the same set of analysis for non-ICS Fridays around the same time window to get a sense of the lead-lag relationship between the futures and cash markets when there is no ICS news announced. For non-ICS Fridays, we don't observe any significant lead-lag relationship between the futures and cash market.

We find strong evidence that the futures market always lead the cash market in the early trading window on ICS announcement days. Our results are consistent with the existing

Table AII: S&P 500 ETF return and turnover on announcement days

	Return			Turnover				
Period	Low	Med	High	Low	Med	High	L-M	H-M
#Days	47	21	63					
△ICS	−2.35***	−0.35	1.90***					
	[−4.03]	[−0.62]	[8.52]					
9:54:58	−4.78***	0.02	4.24***	2.65	0.43	2.17	2.22***	1.74***
	[−6.89]	[0.04]	[7.16]				[2.89]	[3.16]
9:54:59	−1.08**	−0.04	0.11	0.90	0.16	0.57	0.73**	0.40*
	[−2.06]	[−0.17]	[0.38]				[2.32]	[1.85]
9:55:00−9:55:59	−1.95	2.60	1.18	0.39	0.29	0.33	0.10*	0.03
	[−1.15]	[0.98]	[0.75]				[1.68]	[0.64]
9:56:00−9:56:59	−4.21**	1.33	−0.19	0.30	0.24	0.22	0.06	−0.02
	[−2.38]	[0.47]	[−0.14]				[1.14]	[−0.58]
9:57:00−9:57:59	1.02	0.35	0.80	0.25	0.21	0.20	0.03	−0.02
	[0.83]	[0.20]	[0.88]				[0.81]	[−0.48]
9:58:00−9:58:59	1.85	−3.86**	−0.72	0.22	0.18	0.19	0.04	0.01
	[1.16]	[−2.00]	[−0.71]				[0.99]	[0.18]
9:59:00−9:59:59	−0.98	−0.72	−0.18	0.19	0.20	0.17	−0.01	−0.04
	[−0.63]	[−0.36]	[−0.23]				[−0.37]	[−1.20]
9:55:00−9:59:59	−4.26	−0.31	0.89	0.27	0.23	0.22	0.04	−0.01
	[−1.25]	[−0.07]	[0.38]				[1.16]	[−0.25]
10:00:00−10:04:59	1.48	3.78	0.11	0.23	0.27	0.22	−0.04	−0.04
	[0.67]	[0.68]	[0.04]				[−0.77]	[−1.09]
10:05:00−3:59:59	−8.43	50.17**	−3.41	0.10	0.10	0.10	−0.00	−0.00
	[−0.79]	[2.12]	[−0.29]				[−0.00]	[−0.28]
9:30:00−9:54:56	−3.05	4.36	0.36	0.21	0.19	0.20	0.02	0.01
	[−0.45]	[0.54]	[0.08]				[0.80]	[0.49]
9:54:57	−0.88**	−0.15	0.53**	0.33	0.14	0.39	0.20	0.25
	[−2.30]	[−0.75]	[2.17]				[1.27]	[1.32]

The sample period is from January 2008 to June 2013. ICS announcement days are grouped by E-mini S&P 500 price change during 9:54:58 and 9:54:59. The low (high) group contains announcement days when E-mini S&P price moves down (up) by at least one tick during the early peek window, and the medium group contains announcement days with no E-mini S&P price movement during the early peek window. Returns are log returns of S&P 500 ETF for the respective time interval and are in basis points. Turnover is the number of S&P 500 ETF shares traded per second scaled by the total number of S&P 500 ETF shares outstanding. "L-M" and "H-M" indicate the difference in turnover between the low and medium group, and the high and medium group, respectively.

literature on the intra-day price relationship between the futures and cash markets. Previous work such as Kawaller, Koch, and Koch (1987), Stoll and Whaley (1990) and Chan (1992) have documented the asymmetric lead-lag relationship between the futures and the cash markets, i.e. the futures market dominantly leads the cash market and the cash market only weakly leads the futures market. Our results provide additional evidence that the futures market reacts faster and leads the cash market when the information is market-wide. Moreover, with the help of high-frequency tick-by-tick data, we are able to document this information driven lead-lag relationship on time-scales of seconds.

B   Robustness Check for 9:54:57

The contract between the University of Michigan and Thomson Reuters allows for a plus or minus 500 milliseconds margin of error. In other words, Thomson Reuters could send the ICS results to its high-frequency clients as early as 9:54:57.500. In fact, we do observe occasional high trading volume in 9:54:57. We address issues related to early leak at 9:54:57 in this section.

Our tick-by-tick E-mini S&P 500 futures transaction data obtained from CME are only time-stamped to seconds. To check the robustness of our main results, we re-group the announcement days according to futures market's reactions during the full three seconds - 9:54:57, 9:54:58 and 9:54:59. The low and high groups are announcement days when E-mini S&P 500 futures prices move down or up by at least one tick, and the medium group has announcement days when prices don't move in the three seconds. We report the return and volume results for the three groups in Table AIV.

The results in the table AIV are similar to our main findings, except that price movement and trading volume start picking up in the second 9:54:57. The return for the negative and positive news days are -1.37 bps and 0.54 bps, significant and in line with $\triangle$ICS. But the magnitudes are small compared with the average 1.60 bps 1-second return volatility on ICS announcement days. The average trading volume for the negative and positive news days, 339 and 242 contracts respectively, are also slightly higher than the average volume of 68 contracts traded on neutral news days. However, the majority of the early trading still take place at 9:54:58, with 2334 and 1241 contracts traded in the second on average. This suggests that early leak at 9:54:57 is only occasional and doesn't have very large price impact during our sample period. Most importantly, there is no further drift in prices after the public

Table AIII: Lead-lag relationship between the futures market and the cash market

	Panel A: use 9:54:58s to predict returns					**Panel B: use 9:54:59s to predict returns**			
	ICS Announcement Days		Non-news Fridays			ICS Announcement Days		Non-news Fridays	
	R_{59}^{SPY}	R_{00}^{SPY}	R_{59}^{SPY}	R_{00}^{SPY}		R_{00}^{SPY}	R_{01}^{SPY}	R_{00}^{SPY}	R_{01}^{SPY}
	use futures (ES) to predict cash (SPY)					use futures (ES) to predict cash (SPY)			
ϵ_{58}^{ES}	0.387**	0.104	0.175	0.021	ϵ_{59}^{ES}	0.244*	0.022	0.114	0.062
	[2.55]	[1.04]	[1.38]	[0.33]		[1.92]	[0.27]	[1.25]	[0.85]
R_{58}^{SPY}	0.041	−.019	−.450**	0.055	R_{59}^{SPY}	−.082	−.022	−.124	−.011
	[1.17]	[−0.44]	[−2.06]	[0.56]		[−0.87]	[−0.14]	[−1.31]	[−0.23]
AdjR2	0.355	0.038	0.248	0.008	AdjR2	0.048	0.001	0.050	0.001
N	131	131	154	154	N	131	131	154	154
	ICS Announcement Days		Non-news Fridays			ICS Announcement Days		Non-news Fridays	
	R_{59}^{ES}	R_{00}^{ES}	R_{59}^{ES}	R_{00}^{ES}		R_{00}^{ES}	R_{01}^{ES}	R_{00}^{ES}	R_{01}^{ES}
	use cash (SPY) to predict futures (ES)					use cash (SPY) to predict futures (ES)			
ϵ_{58}^{SPY}	0.054	0.104	0.274	−.201	ϵ_{59}^{SPY}	0.122	0.022	0.040	−.095
	[0.69]	[1.04]	[1.53]	[−1.18]		[1.62]	[0.27]	[0.38]	[−1.23]
R_{58}^{ES}	0.038	−.019	−.135	0.037	R_{59}^{ES}	−.261***	−.022	−.427***	0.311***
	[1.13]	[−0.44]	[−1.44]	[0.43]		[−3.18]	[−0.14]	[−6.16]	[3.31]
AdjR2	−.000	0.038	0.089	0.019	AdjR2	0.086	0.001	0.146	0.093
N	131	131	154	154	N	131	131	154	154

The sample is from January 2008 to June 2013. R_t^{ES} is the return of E-mini S&P 500 at the second t, and R_t^{SPY} is the return of SPDR S&P 500 ETF at the second t. ϵ_t^{ES} is the residual term of regression $R_t^{ES} \sim R_t^{SPY} + \epsilon_t^{ES}$ and ϵ_t^{SPY} is the residual term of regression $R_t^{SPY} \sim R_t^{ES} + \epsilon_t^{SPY}$. T-statistics reported in brackets are based on heteroskedasticity robust standard errors.

announcement at 9:55:00. Our main conclusions still hold, except that the early trading and the price discovery process can start in the second half of 9:54:57. But since we don't have E-mini S&P 500 futures transactions at milliseconds level and the early leak at 9:54:57 is not common, we choose to use the 9:54:58 and 9:54:59 as the early trading window for our main results.

C   Prior to Early Peek Arrangement

In this section, we perform a placebo test taking advantage of the period prior to the early peek arrangement. We sort announcement days from January 1999 to June 2006 into three groups based on the price movement of E-mini S&P 500 futures at 9:54:58 and 9:54:59. Since there was no early peek arrangement for high-frequency traders during this period, our sorting should not pick up any information content of ICS. Indeed, as reported in table AV, the two-second return are no longer lined up with the changes of ICS. Average $\triangle$ICS for the ICS announcement days in the low and high groups are not significant from zero, implying that these announcement days are not the ones when ICS shows surprisingly weak or strong readings. There is also no significant increase in trading volume, consistent with the fact that there is no coordinated early trading. Readers shouldn't be surprised at the statistically significant negative and positive return for the low and high groups at 9:54:58 and 9:54:59. This is mainly mechanic since we form groups based on the returns during these two seconds. The returns within these two seconds are in the range between -1.46 bps and 1.70 bps, the sizes are very small especially compared with 1-second return volatility of 1.72 bps. Instead of capturing the information content of ICS, the return at 9:54:58 and 9:54:59, though significant statistically, are not economically significant and simply picking up noises in futures trading.

Table AIV: Sort announcement days based on market reactions during 9:54:57, 9:54:58 and 9:54:59

Period	Return			Volume				
	Low	Med	High	Low	Med	High	L-M	H-M
#Days	44	35	52					
△ICS	−2.67*** [−4.50]	0.35 [0.84]	2.06*** [8.53]					
9:54:57	−1.37*** [−2.61]	0.06 [0.19]	0.54* [1.89]	339	68	242	272* [1.77]	174* [1.67]
9:54:58	−5.40*** [−5.80]	−0.52 [−0.50]	4.69*** [6.83]	2334	825	1241	1509*** [2.85]	415 [1.34]
9:54:59	−0.38 [−1.26]	−0.35 [−1.15]	1.24*** [3.84]	364	170	247	195** [2.24]	78 [1.20]
9:55:00−9:55:59	−0.57 [−0.32]	0.67 [0.44]	0.02 [0.01]	248	185	207	63** [2.10]	22 [1.03]
9:56:00−9:56:59	−3.73* [−1.78]	−0.32 [−0.22]	−0.29 [−0.19]	194	132	143	62*** [2.78]	12 [0.83]
9:57:00−9:57:59	0.98 [0.77]	−0.19 [−0.17]	1.09 [1.19]	148	110	118	38** [2.06]	8 [0.70]
9:58:00−9:58:59	3.36** [2.35]	−1.80 [−1.14]	−1.30 [−1.07]	136	117	105	19 [0.93]	−12 [−0.74]
9:59:00−9:59:59	−1.37 [−0.78]	−1.42 [−1.60]	0.32 [0.34]	118	111	107	7 [0.40]	−4 [−0.30]
9:55:00−9:59:59	−1.33 [−0.37]	−3.06 [−1.00]	−0.16 [−0.07]	169	131	136	38** [2.28]	5 [0.48]
10:00:00−10:04:59	3.59 [1.16]	−2.41 [−0.95]	1.70 [0.53]	158	145	164	13 [0.72]	19 [0.91]
10:05:00−3:59:59	19.29 [1.29]	0.42 [0.03]	−9.63 [−0.73]	64	58	65	7 [1.28]	7 [1.48]
9:30:00−9:54:56	2.43 [0.31]	−9.62*** [−2.60]	3.11 [0.61]	130	108	130	21*** [2.59]	21*** [2.84]

The sample period is from January 2008 to June 2013. ICS announcement days are grouped by E-mini S&P 500 price change during 9:54:57, 9:54:58 and 9:54:59. The low (high) group contains announcement days when price moves down (up) by at least one tick during the three seconds from 9:54:57 to 9:54:59, and the medium group contains announcement days with no price movement during the three seconds from 9:54:57 to 9:54:59. Returns are log returns for the respective time interval and are in basis points. Volume is the number of contracts traded per second. "L-M" and "H-M" indicate the difference in volume between the low and medium group, and the high and medium group, respectively.

Table AV: **Placebo test for the period prior to the early peek arrangement**

Period	Return			Volume				
	Low	Med	High	Low	Med	High	L-M	H-M
#Days	40	135	47					
△ICS	−0.71 [−1.20]	0.13 [0.55]	0.02 [0.06]					
9:54:58	−1.44*** [−6.32]	0.01 [0.10]	1.31*** [5.27]	53	27	22	26 [1.45]	−5 [−0.60]
9:54:59	−1.46*** [−7.67]	−0.01 [−0.10]	1.70*** [7.11]	20	35	49	−15 [−1.18]	14 [0.82]
9:55:00−9:55:59	−0.15 [−0.16]	−0.83 [−1.60]	−1.17 [−1.01]	25	27	30	−3 [−0.42]	3 [0.47]
9:56:00−9:56:59	0.67 [0.73]	−0.66 [−1.08]	0.46 [0.45]	23	26	25	−4 [−0.69]	−1 [−0.27]
9:57:00−9:57:59	0.96 [0.77]	−0.65 [−1.37]	0.06 [0.05]	29	28	25	1 [0.10]	−3 [−0.57]
9:58:00−9:58:59	0.02 [0.02]	0.63 [1.28]	−0.03 [−0.03]	26	27	26	−0 [−0.08]	−1 [−0.17]
9:59:00−9:59:59	−0.84 [−0.58]	0.25 [0.46]	−0.23 [−0.23]	25	25	23	0 [0.02]	−2 [−0.35]
9:55:00−9:59:59	0.67 [0.24]	−1.25 [−0.85]	−0.91 [−0.46]	25	27	26	−1 [−0.25]	−1 [−0.19]
10:00:00−10:04:59	3.13 [0.93]	−0.55 [−0.34]	1.12 [0.44]	35	34	33	1 [0.15]	−1 [−0.09]
10:05:00−3:59:59	−16.5 [−1.28]	6.26 [0.94]	−9.87 [−0.60]	13	13	12	−1 [−0.28]	−1 [−0.38]
9:30:00−9:54:56	−5.97 [−0.88]	−2.02 [−0.87]	−2.58 [−0.50]	31	27	26	4 [0.77]	−0 [−0.11]
9:54:57	0.38* [1.74]	0.13 [0.69]	−0.63** [−2.45]	32	44	28	−11 [−0.50]	−15 [−0.74]

The sample period is from Sep 1997 to Dec 2006, the period prior to the early peek arrangement. ICS announcement days are grouped by E-mini S&P 500 price change during 9:54:58 and 9:54:59. The low (high) group contains announcement days when price moves down (up) by at least one tick during the early peek window, and the medium group contains announcement days with no price movement during the early peek window. Returns are log returns for the respective time interval and are in basis points. Volume is the number of contracts traded per second. "L-M" and "H-M" indicate the difference in volume between the low and medium group, and the high and medium group, respectively.

References

Andersen, T. G., T. Bollerslev, F. X. Diebold, and C. Vega (2003). Micro Effects of Macro Announcements: Real-Time Price Discovery in Foreign Exchange. *American Economic Review 93*(1), 38–62.

Balduzzi, P., E. J. Elton, and T. C. Green (2001, 12). Economic News and Bond Prices: Evidence from the U.S. Treasury Market. *Journal of Financial and Quantitative Analysis 36*, 523–543.

Brogaard, J., T. Hendershott, and R. Riordan (2012). High frequency trading and price discovery. Working Paper, UC Berkeley Haas.

Chae, J. (2005). Trading Volume, Information Asymmetry, and Timing Information. *Journal of Finance 60*(1).

Chan, K. (1992). A Further Analysis of the Lead–Lag Relationship Between the Cash Market and Stock Index Futures Market. *The Review of Financial Studies 5*(1), pp. 123–152.

Fleming, M. J. and E. M. Remolona (1999). Price Formation and Liquidity in the U.S. Treasury Market: The Response to Public Information. *The Journal of Finance 54*(5), pp. 1901–1915.

Grossman, S. J. (1976). On the Efficiency of Competitive Stock Markets Where Trades Have Diverse Information. *The Journal of Finance 31*(2), pp. 573–585.

Grossman, S. J. and J. E. Stiglitz (1980). On the impossibility of informationally efficient markets. *American Economic Review 70*, 393–408.

He, H. and J. Wang (1995). Differential Information and Dynamic Behavior of Stock Trading Volume. *The Review of Financial Studies 8*(4), pp. 919–972.

Kawaller, I. G., P. D. Koch, and T. W. Koch (1987). The Temporal Price Relationship between S&P 500 Futures and the S&P 500 Index. *The Journal of Finance 42*(5), 1309–1329.

Kyle, A. S. (1985). Continuous Auctions and Insider Trading. *Econometrica 53*(6), pp. 1315–1335.

Stoll, H. R. and R. E. Whaley (1990). The Dynamics of Stock Index and Stock Index Futures Returns. *Journal of Financial and Quantitative Analysis 25*(04), 441–468.

Wang, J. (1993, April). A Model of Intertemporal Asset Prices under Asymmetric Information. *Review of Economic Studies 60*(2), 249–82.