Journal of Financial Economics 126 (2017) 399–421

Contents lists available at ScienceDirect

Journal of Financial Economics

journal homepage: www.elsevier.com/locate/jfec

# Early peek advantage? Efficient price discovery with tiered information disclosure☆

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ARTICLE INFO

*Article history:*
Received 13 October 2015
Revised 12 August 2016
Accepted 10 September 2016
Available online 1 August 2017

*JEL classification:*
D82
G14
G18

*Keywords:*
Early peek
Information disclosure
Price discovery
High frequency trading

ABSTRACT

From 2007 to June 2013, a small group of fee-paying, high-speed traders receive the Michigan Index of Consumer Sentiment two seconds before its broader release. Within this early peek window, we find highly concentrated trading and a fast price discovery of less than 200 milliseconds. Outside this narrow window, general investors trade at fully adjusted prices. We further establish a causal relationship between the early peek mechanism and the fast price discovery by isolating the impact of the early peek arrangement along two dimensions. In cross section, we use other news releases without the early peek (as controls); in time series, we use the sudden suspension of the early peek arrangement in July 2013 (as the treatment). Our difference-in-difference tests directly connect the early peek arrangement to more efficient price discovery — it results in faster price discovery, lower volatility, and faster resolution of uncertainty. These results show that contrary to the common perception, tiered information release may help to reduce, rather than enhance, the informational advantage of faster traders and improve the efficiency of the price discovery process in financial markets.



## 1. Introduction

How information actually transmits and impounds into market prices remains 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 different clients offers a rare instance in which 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 trading and influences the market.

The University of Michigan Index of Consumer Sentiment (ICS), which is based on nationwide telephone surveys of households, has long been considered a key

☆ We are grateful to G. William Schwert (the editor), the anonymous reviewer, Jonathan Brogaard, and Haoxiang Zhu for valuable discussions. We also thank seminar participants at the 2015 American Finance Association Meetings, the Program in Law and Economics of Capital Markets at Columbia University, the Cheung Kong Graduate School of Business, and the National University of Singapore. We thank Cathy Fang for excellent research assistance.

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[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.

http://dx.doi.org/10.1016/j.jfineco.2017.07.007
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reading of U.S. consumer confidence. Its release has been closely watched, and substantial changes in ICS often move financial markets. Since 2007, Thomson Reuters has obtained the exclusive right in disseminating the survey results, 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 clients at 9:54:58, two seconds earlier than the broader release at 9:55:00. Since June 2013, this practice has attracted broad media coverage, as well as a review by the office of the New York Attorney General. In July 2013, less than one month after the initial coverage, Thomson Reuters suspended 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 market? In which way does this tiered information release arrangement affect the efficiency of the price discovery process? Specifically, what is the speed and quality of price discovery with and without this tiered information release? Answers to these questions can have broad implications on the optimal design of the information disclosure process in the market and the corresponding regulatory policies.

In order to answer these questions, we examine in detail the price dynamics and trading activity in E-mini Standard&Poors 500 futures around ICS releases during this episode. We focus our empirical investigation on S&P 500 futures because ICS, reflecting consumers' opinions of the general economy, has the ability to move the aggregate market. 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 marketwide information.[3]

From January 2009 to June 2013, when Thomson Reuters offers the early peek arrangement, we find abnormally high trading volume of E-mini S&P 500 futures at 9:54:58 on ICS announcement days.[4] On average, the trading volume jumps to 2,855 contracts per second at 9:54:58, well above the average of 87 contracts per second on the non-news days. In the following second, 9:54:59, the abnormal volume drops to 398 contracts, still well above the sample average but sharply down from the volume at 9:54:58. In other words, although those fee-paying, high-speed traders have an advantage of two seconds ahead of general investors, the first second at 9:54:58 is disproportionately more meaningful to them. By contrast, on non-ICS announcement Fridays, we do not find any abnormal trading volume at 9:54:58 or 9:54:59.

Along with the high trading volume, most of the price adjustments occur during the first second of 9:54:58 as well. On negative news days, the one-second return at 9:54:58 is −10.40 bps with a *t*-statistic of −8.24, while the return at 9:54:59 is only 0.12 bps and statistically insignificant.[5] Similarly, on positive news days, the return at 9:54:58 is 6.92 bps with a *t*-statistic of 6.42, while the return at 9:54:59 is −0.32 bps and statistically insignificant. Calibrating the speed of price discovery at a finer scale, we find that the first 200 milliseconds at 9:54:58 accounts for 89% of the one-second return at 9:54:58 on negative news days, and 85% of the one-second return at 9:54:58 on positives news days. In other words, most of the price discovery happens during the first 200 milliseconds, faster than the blink of an eye. Similarly, transaction volume is also disproportionately concentrated during the first 200 milliseconds of the trades. For both negative and positive news, around 75% of the total transaction volume at 9:54:58 takes place during the first 200 milliseconds. The remaining 25% of the trades are traded around fully adjusted prices and are not important in price discovery.

At 9:55:00, the early peek window closes and the ICS results are announced to general investors. For them and for the integrity of the market, understanding the price behavior after the early peek trading is important. We find no significant price drift immediately after the public announcement, regardless of the intensity of the news embedded in the ICS release. In other words, because of the intense and 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 meaningful trading signal, and the general investors trade at the fully adjusted market prices. As such, the scope of the early peek advantage, if any, is narrowly contained and limited to high-speed traders trading mostly 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.[6]

This empirical evidence suggests that the early peek arrangement can potentially improve the efficiency of price discovery. In this paper, we attempt to further establish this causal relationship by formally testing the hypothesis that the early peek arrangement leads to a more efficient

[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.

[3] 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 Exchange-traded Fund (ETF) and find very similar results. One could also imagine index options such as S&P 500 index options as a suitable venue to trade on such information.

[4] For this paper, the volume or return at a given second, say 9:54:58, indicates the volume or return realized over that second.

[5] We sort the announcement days into three groups based on the index surprise, measured as the actual release minus the median of economists' forecasts surveyed by Bloomberg. The low, medium, and high groups contain the preliminary ICS announcement days with the bottom 40%, the middle 20%, and the top 40% index surprise. The low and high groups contain the announcement days with negative and positive surprises and move the E-mini S&P 500 futures down and up, respectively. By contrast, the medium group contains the announcement days with small surprises and only mildly moves the E-mini S&P 500 if at all.

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

price discovery process. We do so by isolating the impact of the early peek arrangement in two separate dimensions. Along the cross-sectional dimension, we make use of the fact that there are other comparable macroeconomic indices whose news announcements do not have the early peek arrangement. Along the time-series dimension, we take advantage of the sudden suspension of the early peek arrangement for ICS in July 2013. Relative to ICS during the early peek period, the cross-sectional comparison gives us a control group without the early peek arrangement, and the time-series comparison gives us a time period over which the early peek arrangement for ICS is turned off. As such, the cross-sectional and time-series differences provide two independent tests to help us uniquely identify the impact of the early peek arrangement. Moreover, taking advantage of the difference-in-difference tests, we can further control for any cross-sectional or time-series variations that are not related to the early peek arrangement.

We first test the hypothesis that the early peek arrangement helps facilitate faster price discovery. For this, we measure the price impact of news announcements over three separate time horizons: the initial one second (0s) right after the news release, the next four seconds (1 – 4 s), and the last five seconds (5 – 9 s). For ICS during early peek, a one standard deviation surprise in ICS on average moves the initial one-second return by 8.26 basis points, which is statistically significant. Over the next four seconds, the price impact coefficient is slightly negative (−0.44 basis points) and is no longer statistically significant. This is consistent with our earlier observations that, with the early peek program in place, the price discovery process happens within the first 200 milliseconds, with no further price drift. For comparison, we use the manufacturing index of the Institute for Supply Management (ISM). In particular, we use ISM's non-manufacturing index (ISMN) as a cross-sectional control. We find that, for the sample time period, a one standard deviation surprise in ISMN index on average gives the initial one-second return by 8.45 basis points, similar in magnitude to that of ICS. But over the next four seconds, the price impact coefficient for ISMN remains positive (3.07 basis points) and statistically significant, indicating continuing price drift after the initial second. Compared with the lack of further price drift for ICS, this difference in the speed of price discovery between ICS and its control provides the first direct test that the early peek arrangement for ICS leads to faster price discovery than that for the control group.

Our results can be further sharpened and strengthened by adding the time-series dimension. Taking advantage of the sudden suspension of the early peek arrangement, we measure the price impact of ICS announcements in the post period. Overall, we find a weaker price impact across the board for ICS as well as the ISM indices. Against this backdrop of reduced price impact, however, we observe an emergence of continuing price drift after the initial second for ICS in the post early peek period. In particular, over the next four seconds (1 – 4 s), the price impact of ICS becomes positive and significant, a direct contrast to the lack of further price drift during the early peek period. For ISMN, early peek is absent in both time periods, and, not surprisingly, we observe significant further price drift in both time periods. Using ISMN as a control, our final difference-in-difference test is robust to cross-sectional or time-series variations that are unrelated to the early peek arrangement. Indeed, our result shows that the difference in price drift remains significant and important, linking the faster price discovery for ICS during early peek uniquely to the arrangement itself.

In addition to ISMN, we also include the ISM manufacturing index (ISMM) as a separate control. Overall, the price impact of ISMM is slightly larger than that of ICS and ISMN, making it a slightly more important index. Nevertheless, this cross-sectional difference, which is unrelated to the early peek arrangement, does not affect our results. Focusing on the pair of ICS and ISMM and performing the same difference-in-difference tests, we obtain very similar results. Namely, because of the lack of the early peek arrangement, there is further price drift for ISMM in both time periods, before and after the suspension of early peek. Consequently, the cross-sectional difference in the further price drift between ISMM and ICS is statistically significant during the early peek period but insignificant in the post period. The final difference-in-difference in price drift remains significant and important, again attributing the faster price discovery for ICS uniquely to early peek. Finally, we also use the pair of ISMN and ISMM as a placebo test. As expected, the difference-in-difference tests do not reveal any significant results. This is not surprising, given that for both ISMN and ISMM, early peek is absent both during and post the early peek period for ICS.

We next test the hypothesis that the early peek arrangement helps improve the precision of the price discovery process. We do so by investigating the impact of early peek on volatility. While returns or prices capture the average effect of price discovery, volatility captures the quality or the precision of the price discovery process. Using trade-by-trade returns, we calculate the scaled return volatility of E-mini S&P 500 as the ratio between the event volatility surrounding the news release and the steady-state volatility ten minutes after the release. We examine the volatility behavior in two dimensions, its convergence to steady state after the news release and the difference-in-difference tests on its overall level.

For convergence, we find that volatility spikes up when the news first hits the market for all three indices but then recovers to the steady-state level. However, in the case of ICS with tiered information release, the convergence is much faster. In particular, one second after the initial news release, the scaled volatility converges at a rate of 52% for the ICS, while for ISMN and ISMM, its convergence rate is only 21% and 29%, respectively. For the next second, the convergence rate drops to 17% for the ICS but remains steady at 21% for ISMN and 28% for ISMM. Clearly, under the tiered release arrangement, the high volatility environment lasts for only a second or two, while under the uniform release arrangement, the high volatility environment lasts quite a bit longer, for at least four or five seconds.

We can further test our hypothesis by performing the difference-in-difference tests on the level of volatility. Again, using ISMN as a control, we examine the cross-sectional difference in volatility, taking advantage of the fact that, during the early peek period, only ICS has the early peek arrangement. Over the initial second right after the announcement, there is no significant cross-sectional difference between the control and treatment, indicating similar impact on volatility. Over the next four seconds, however, the cross-sectional difference in volatility kicks in, reflecting a faster decay in volatility and a lower overall volatility for ICS because of the early peek arrangement. Taking advantage of the fact that neither ICS nor ISMN has the early peek advantage after the suspension of the program, we test this difference in volatility in a difference-in-difference test. It remains significant, attributing the lower volatility for ICS uniquely to the early peek arrangement.

Our results on volatility indicate that the benefit of tiered information release is reflected not only in faster information incorporation but also in lower excess volatility and faster resolution of uncertainty. One might argue that the response in return adds up in the sense that, with a slower price discovery, information eventually gets incorporated into prices. By contrast, the corresponding response in volatility, its higher level over longer periods, is a deadweight loss, cumulative over time, and sunk into the trading process. For market participants, high volatility implies higher execution risk and liquidity cost.

In terms of speed and precision, our empirical results demonstrate that the early peek arrangement could actually improve the efficiency of the price discovery process. This raises interesting questions regarding the design of more efficient mechanisms in disseminating market-moving news.

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 releases 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 most crucial difference is in the nature of the information structure. Unlike existing studies that focus only on public news, our paper takes advantage of the multitiered 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-speed traders at exactly two seconds before the public release. This feature of selective disclosure gives us a unique opportunity to study how private information is priced into the market through concentrated trading among a certain group of market participants. Additionally, taking advantage of high-speed 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 recent studies on high frequency trading and its impact on price discovery.[7] 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. In particular, the price discovery during the first 200 milliseconds happens overwhelmingly among concentrated high frequency trading, with very little involvement of other market participants. Through a set of formal cross-sectional, cross-time, and difference-in-difference tests, we link the faster price discovery and lower volatility on the ICS announcement days directly to its multitiered releasing mechanism.

Several additional comments are in order to help clarify and interpret our empirical findings. First, our analysis suggests that tiered information release helps to improve the informational efficiency of the market, i.e., to allow information impounded into prices faster. It is worth noting that informational efficiency does not automatically imply the overall efficiency of the market, such as in capital allocation or welfare. However, as shown theoretically in Vayanos and Wang (2012), among others, improving the market's informational efficiency and thus reducing the information asymmetry between trading counterparties can also improve the market's allocational efficiency.[8] Thus, even though our findings do not definitely speak to the overall impact of tiered information release on the market, they do demonstrate specific gains in informational efficiency, which may lead to overall net gains, as theory suggests.

Second, as indicated at the beginning of the paper, our focus here is not merely on the effect of early peek of ICS release per se, but rather to use it to examine, in a controlled setting, the impact of tiered information release. Issues concerning how information should be released are important not only for our understanding of how the financial markets function but also for policy. Regulations like Reg FD (Fair Disclosure) typically weight more on simple fairness arguments rather than thorough economic considerations. Our study shows that more careful economic analysis is needed in providing a full and scientific picture about the tradeoffs concerning different arrangements of information release. This is particularly true given that the economic mechanism we identify empirically should work for other types of information releases in general, ranging from macro to firm-level news.

Third, in the presence of high frequency traders, it is natural to assume that they are more likely to be those who benefit from the early peek advantage over other traders. Our empirical analysis in fact shows the opposite could be true. The tiered information release actually attracts the fast traders to first trade among themselves, which leads to faster incorporation of the information into prices and reduces their information advantage

[7] For example, Brogaard, Hendershott and Riordan (2014) study the role of high frequency trading in price discovery and show some evidence that high frequency traders contribute to price efficiency.

[8] In fact, there is a direct analogy between the early peek arrangement and the full information situation examined in Vayanos and Wang (2012): With early peek, traders with the early peek of the news will trade among themselves first, which leads to the full incorporation of the news in the price, thus eliminating any information asymmetry in subsequent trading. With no early peek, on the other hand, faster traders, by receiving/processing the news faster, will trade with the rest of the market with an information advantage. This corresponds to the asymmetric information situation in their model. They show that the price level and welfare are both higher under full information than under asymmetric information. Similar results can also be inferred from several related papers, such as Easley and O'Hara (2004) and He and Wang (1995).

over other traders. This conclusion, however, should not be interpreted as an endorsement of high frequency traders or advocating giving them even more information advantage. The merits of high frequency trading depend on multiple factors, which are the focus of many recent studies but not part of our analysis.[9] We take as given that traders receive and/or process information at different speeds and examine the implication of tiered information release in this situation. We show that early peek actually helps to reduce, rather than enhance as the initial impression might suggest, the informational advantage of the faster traders.

The rest of paper is organized as follows. Section 2 describes the early peek arrangement. Section 3 summarizes the data used in this paper. Section 4 reports the results on abnormal early trading volume and the price impact of the early trading. Section 5 investigates the impact of the early peek arrangement on the speed of price discovery. Section 6 investigates the impact of early peek on the level of volatility. Section 7 concludes the paper. In the Appendices, we report the results for the cash market, investigate the market depth around the announcement time, and address potential stale order issues.

## 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 gross domestic product (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 very 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 9:54:58 Eastern Standard Time (EST), when Thomson Reuters sends out ICS numbers, in a specialized machine readable format, to a small group of fee-paying, high-speed clients.[10] 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 1,200 economic indicators in formats specially designed for algorithm trading. This special arrangement only came to light after a series of front page articles that 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 nongovernment 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 the New York Attorney General, who is conducting an ongoing investigation into the distribution of sensitive economic data. From July 2013 on, ICS results are released to all Thomson Reuters regular subscribers at 9:55:00. On October 7, 2014, Bloomberg announced that it will become the new distributor for ICS as of January 2015, with uniform release at 10:00:00.

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 subscribers obtained the information at the same time.[11] But how the ICS numbers are distributed to nonsubscribers 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

[9] See, for example, Easley, de Prado and O'Hara (2012), Menkveld (2013), Budish, Cramton and Shim (2015), and Kirilenko, Kyle, Samadi and Tuzun (2017).

[10] 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 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 very few occasions, high-speed traders could get the data as early as 9:54:57.500.

[11] When it was alleged that Market News International, a news website, published an article including the ICS numbers before the data were 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.

receives the ICS numbers.[12] 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 9:45:00 or 10:00:00, 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/ISMN/ISMM announcements

The Index of Consumer Sentiment (ICS) is released twice every month, whose value is normalized to one hundred in December 1964. The preliminary numbers are usually announced on the second Friday of the month, and the revised final figures are typically announced on the fourth Friday. Since most of the market-moving information is contained in the preliminary announcements every month, we consider only ICS's preliminary announcements in our analysis. Our results stay robust if we include the final announcements in our sample.

The ISM non-manufacturing (ISMN) and ISM manufacturing (ISMM) indices are compiled by the Institute for Supply Management. The ISMN index is based on the surveys of more than 400 managers of non-manufacturing firms and is released at 10:00:00 EST on the sixth business day of every month; the ISMM index is based on the surveys of more than 300 managers of manufacturing firms and is released at 10:00:00 EST on the first business day of every month. Both the ISMN and ISMM indices are benchmarked to 50, with values above 50 being usually suggestive of expansion, while those below 50 are usually suggestive of contraction.

For each of the index announcements, we collect the release date, index number, and economists' forecast numbers from Bloomberg. Table 1 reports the summary statistics of the ICS, ISMN, and ISMM indices. We separate the sample into two periods: during and post the early peek arrangement. We choose the period during which the early peek arrangement is in place from January 1, 2009 to June 30, 2013. The post period when the early peek arrangement is suspended is from July 1, 2013 to June 3, 2016. Although the early peek arrangement started in 2007, we do not include year 2007 in our sample because we cannot identify the exact date in 2007 when Reuters started distributing ICS in multiple tiers. We also exclude 2008 because the E-mini S&P 500 transactions data that we obtain from the Chicago Mercantile Exchange (CME) start only from January 2009.[13] ICS was released 54 times during our sample period with the early peek arrangement. For the post early peek period, ICS was released 35 times, however, one announcement day was on a nontrading day, so we end up with 34 observations. For ISMN and ISMM, the number of observations is 53 for the period with the early peek arrangement and 36 for the period post the early peek arrangement.

To capture the information content of index announcements, we calculate the index surprise as the difference between the actual index and the median of the economists' forecasts surveyed by Bloomberg. During the early peek period from January 2009 to June 2013, the average surprises of the three indices are all close to zero: −1.08 for ICS, 0.12 for ISMN, and 0.45 for ISMM. The standard deviation of ICS surprises is 3.68, higher than the standard deviation of the ISMN surprises (1.55) and ISMM surprises (1.83). This is mainly due to the different nor-

**Table 1**
Summary statistics.
Index surprise is the actual index value minus the median of the economists' forecasts surveyed by Bloomberg. ICS is the preliminary release of the Index of Consumer Sentiment, ISMN is the ISM Non-Manufacturing index, and ISMM is the ISM Manufacturing index. For each index announcement day, "0s" denotes the first second after the announcement; "(1 –4 s)" denotes the four-second window from the second to the fifth second after the announcement; "(5 – 9 s)" denotes the five-second window from the sixth to the tenth second after the announcement. For each of the three time windows after index announcements, we report the volatility of the log returns and the average trading volume per second of E-mini S&P 500 during the respective time windows. The volatility, reported in terms of basis points, is the standard deviations of one-second, four-second, and five-second log returns; volumes are reported in terms of number of contracts per second. The "Non-news" refers to the time window from 10:35:30 to 10:40:30 on the third Friday of each month, which is a non-ICS day and contains no other major news announcements. For the "Non-news," volatility is calculated based on one-second, four-second, and five-second log returns, and the trading volume is the number of contracts traded per second.

| Variable | ICS | ISMN | ISMM | Non-news |
|---|---|---|---|---|
| *Panel A: during early peek (Jan 2009 – Jun 2013)* | | | | |
| Average index | 70.39 | 52.56 | 52.54 | |
| Average index surprise | −1.08 | 0.12 | 0.45 | |
| Std of index surprise | 3.68 | 1.55 | 1.83 | |
| Volatility of return 0 s | 9.42 | 9.03 | 12.68 | 1.53 |
| Volatility of return (1 – 4 s) | 3.62 | 7.12 | 7.52 | 2.12 |
| Volatility of return (5 – 9 s) | 4.75 | 5.03 | 6.96 | 2.27 |
| Average volume per sec 0 s | 2855 | 2247 | 3792 | 87 |
| Average volume per sec (1 – 4 s) | 385 | 738 | 777 | |
| Average volume per sec (5 – 9 s) | 387 | 440 | 656 | |
| *Panel B: post early peek (Jul 2013 – Jun 2016)* | | | | |
| Variable | ICS | ISMN | ISMM | Non-news |
| Average index | 87.10 | 55.98 | 53.52 | |
| Average index surprise | −0.53 | 0.16 | 0.12 | |
| Std of index surprise | 3.43 | 1.70 | 1.52 | |
| Volatility of return 0 s | 2.21 | 2.59 | 3.48 | 0.90 |
| Volatility of return (1 – 4 s) | 2.26 | 3.08 | 2.02 | 1.23 |
| Volatility of return (5 – 9 s) | 1.24 | 1.73 | 1.98 | 1.34 |
| Average volume per sec 0 s | 426 | 527 | 833 | 54 |
| Average volume per sec (1 – 4 s) | 123 | 165 | 187 | |
| Average volume per sec (5 – 9 s) | 84 | 130 | 163 | |

[12] We downloaded the ICS release times 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.

[13] We also perform a set of robustness checks by including years 2007 and 2008 in our sample period with the early peek arrangement by using the "Time & Sales" data set provided by CME, which starts in 1996 but only contains timestamps in seconds. The results are robust.

malization benchmarks used in the indices' construction. Therefore, to make the three index surprises directly comparable, we also standardize the index surprises by their own "long term" standard deviations in our later cross-sectional and cross-time tests. We estimate the long term standard deviation of each index using all the index announcements over a longer period from May 1, 1999 to June 3, 2016.

During the post early peek period, the average level of ICS is 87.10, which is around 17 points higher than the average level of 70.39 for the period during the early peek arrangement. This is a reflection of consumer pessimism following the 2007 – 2009 financial crisis and the subsequent improvement in consumer sentiment during recent years. In terms of ICS surprise, however, the numbers are quite comparable across time. The average ICS surprise is -0.53, only slightly (but not statistically) more positive than the average of −1.08 during the period with the early peek arrangement. The standard deviation of ICS surprise is 3.43 during the post peek period, close to the standard deviation of 3.68 for the period with the early peek arrangement. Similarly, we also find that the distribution of the ISMN and ISMM surprises are comparable for the period with the early peek arrangement and the post peek period without the early peek arrangement. This indicates that there is no systematic shift in the informativeness of the index announcements, and the only major difference between the two sample periods is how ICS news is released.

### 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, ISMN, and ISMM are all reflections 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 the most liquid instrument and is less affected by short sale constraints. Similar results from the cash market are reported in Appendix A. Our main data source comes from the "Market Depth" data set provided by the Chicago Mercantile Exchange (CME). The data set contains all trade messages of E-mini S&P 500 with millisecond timestamps starting from January 2009. 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.

In Table 1, we also report the average trading volume and the volatility of returns of the E-mini S&P 500 for different time windows after the index announcements. For each index announcement day, "0s" denotes the first second after the announcement; "(1 – 4s)" denotes the four-second window from the second to the fifth second after the announcement; "(5– 9s)" denotes the five-second window from the sixth to the tenth second after the announcement. For each of the three time windows after index announcements, we report the standard deviation of the log returns ("Volatility of ret") and the average trading volume per second ("Average volume per sec") for the most active E-mini S&P 500 contract across all the ICS/ISMN/ISMM announcement days in the respective sample period. In addition, we also report some benchmarks of volatility and trading volume of the most liquid E-mini S&P 500 contracts on the non-news days. For the third Friday of each month ("Non-news"), the "Volatility of ret" is the standard deviation of one-second, four-second, and five-second log returns and the "Average volume per sec" is the average volume per second of the most liquid E-mini S&P 500, estimated using a time window from 10:35:30 to 10:40:30, which contains no macro news announcements. The volatilities are reported in terms of basis points, and the volumes are reported in terms of number of contracts per second.

At the first second after the index announcement, the return volatility and trading intensity on ICS announcement days are close to those on the ISMN announcement days and slightly lower compared to those on the ISMM announcement days. During the early peek period, the volatility of the returns during the first second after ICS announcements (0s) is 9.42 basis points, compared to 9.03 basis points for ISMN announcements and 12.68 for ISMM announcements. For all three indices, the volatility at the first second after the announcements is significantly higher than the one-second volatility of 1.53 basis points on non-news days, reflecting the price adjustment after the news releases. After the first second, the volatility reduces quickly on the ICS days but much more slowly for the ISMM and ISMN days. The volatility of the four-second return during the (1 – 4 s) window is 3.62 basis points for ICS days, significantly lower than the volatility on the ISMN days (7.12) and on the ISMM days (7.52). After the first five seconds, the volatility on the ICS days becomes close to the volatility on the ISMN and ISMM days. The volatility of the five-second return from (5 – 9 s) is 4.75 basis points on ICS days, compared to 5.03 basis points on ISMN days and 6.96 basis points on ISMM days.

The trading volume exhibits a very similar pattern. The average trading volume at the first second after ICS announcements is 2,855 contracts, compared with the average volume of 2,247 contracts on ISMN days and 3,792 contracts on ISMM days. After the first second, the average trading volume drops quickly to 385 contracts per second during (1 – 4 s) and 387 contracts during (5 – 9 s). By comparison, the average trading volume on ISMN and ISMM days also reduces though not as much as those on ICS days. The average trading volume during (1 – 4 s) is 738 contracts on ISMN days and 777 contracts on ISMM days; the average trading volume during (5 – 9 s) is 440 contracts on ISMN days and 656 contracts on ISMM days.

For the sample period post the early peek, the return volatility and trading intensity on ICS days are also close to those on the ISMN days and slightly lower than those on the ISMM announcements. However, compared with the period with the early peek, we observe significant lower return volatility and trading intensity across all three index announcements. The average one-second volatility at 0s drops from 9.42 to 2.21 bps on ICS days, from 9.03 to 2.59 bps on ISMN days, and from 12.68 to 3.48 basis points on ISMM days. Although the volatilities on the news announcement days are still higher than those on

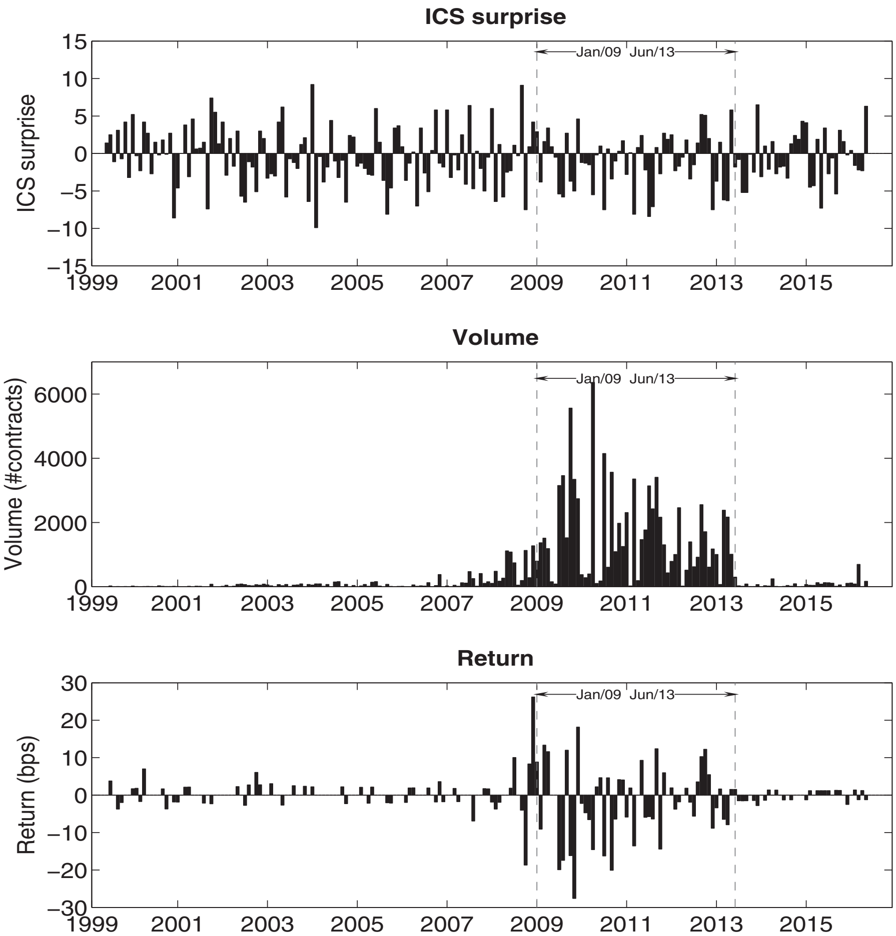


**Fig. 1.** Time series of ICS surprise, two-second volume, and return of E-mini S&P 500 at 9:54:58 and 9:54:59. The sample contains all the preliminary ICS announcement days from May 1999 to June 2016. ICS surprise is the difference between the ICS and the median of economists' forecast numbers surveyed by Bloomberg. 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 9:54:58 and 9:54:59.

the non-news days (0.90 basis points), the magnitudes are substantially lower than those during the early peek period. Similarly, the trading volume also reduces substantially during the post peek period. This observation is interesting as the suspension changes only the releasing mechanism of the ICS index and has no impact on the releasing mechanism of ISMN and ISMM indices, which are always announced at 10:00:00 to all investors. Moreover, as seen in Table 1, none of the indices show any significant shift of informativeness during the post period. Combining this evidence, we suspect that the suspension of the early peek arrangement of ICS could have had a marketwide impact on the high-speed trading based on low latency news feed, including those non-ICS indices.[14]

## 4. Early peek trading of ICS release

### 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 to 9:54:59 on ICS announcement days. For all ICS announcement days from May 14, 1999 to June 3, 2016, Fig. 1 plots the time series of ICS surprise 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 2009 to June 2013 but very little abnormal trading prior to or post the early peek arrangement.[15] By contrast, the top panel shows that ICS surprise, which measures the information content of ICS, exhibits the same level

[14] For example, we also observe similar reduced trading on the Nonfarm Payrolls announcement days during the post peek period. Nonfarm Payrolls announcements are always announced to the public at 8:30:00 EST.

[15] To be more precise, the large spikes in two-second transaction volume start as early as January 2008. Considering the data availability, we skip 2008 and define January 2009 to June 2013 as the early peek period.

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 Fig. 1, large two-second returns, in both positive and negative directions, are very common during the period with early release. Moreover, the correlation between ICS surprise and the two-second early peek return is 0.80 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 ICS surprise. Similarly, after the early peek arrangement was suspended in July 2013, large trading volume and returns disappeared, even though there were several large positive and negative ICS surprise announcements during this period.

Putting together this evidence, there is very little doubt that the abnormally high trading volume during the early peek window comes from the trading of fast 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 financial markets, the large magnitudes of the two-second return at 9:54:58 and 9:54:59 on ICS announcement days is not a result of higher market volatility. For this sample period, the two-second volatility, sampled from 9:50:00 to 9:59:59, is on average 1.91 bps, with the lower and upper 25% values at 1.46 bps and 2.24 bps, respectively. By contrast, many of the two-second returns realized over those two-second early peek windows are on the order of ten 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, Fig. 2 plots average second-by-second trading volume of E-mini S&P 500 futures from 9:52:00 to 9:59:59 across the total 54 preliminary ICS announcement days from January 2009 to June 2013. The most striking observation is the huge upwards spike in trading volume, happening at exactly 9:54:58 on ICS announcement days. On average, there are 2,855 E-mini S&P 500

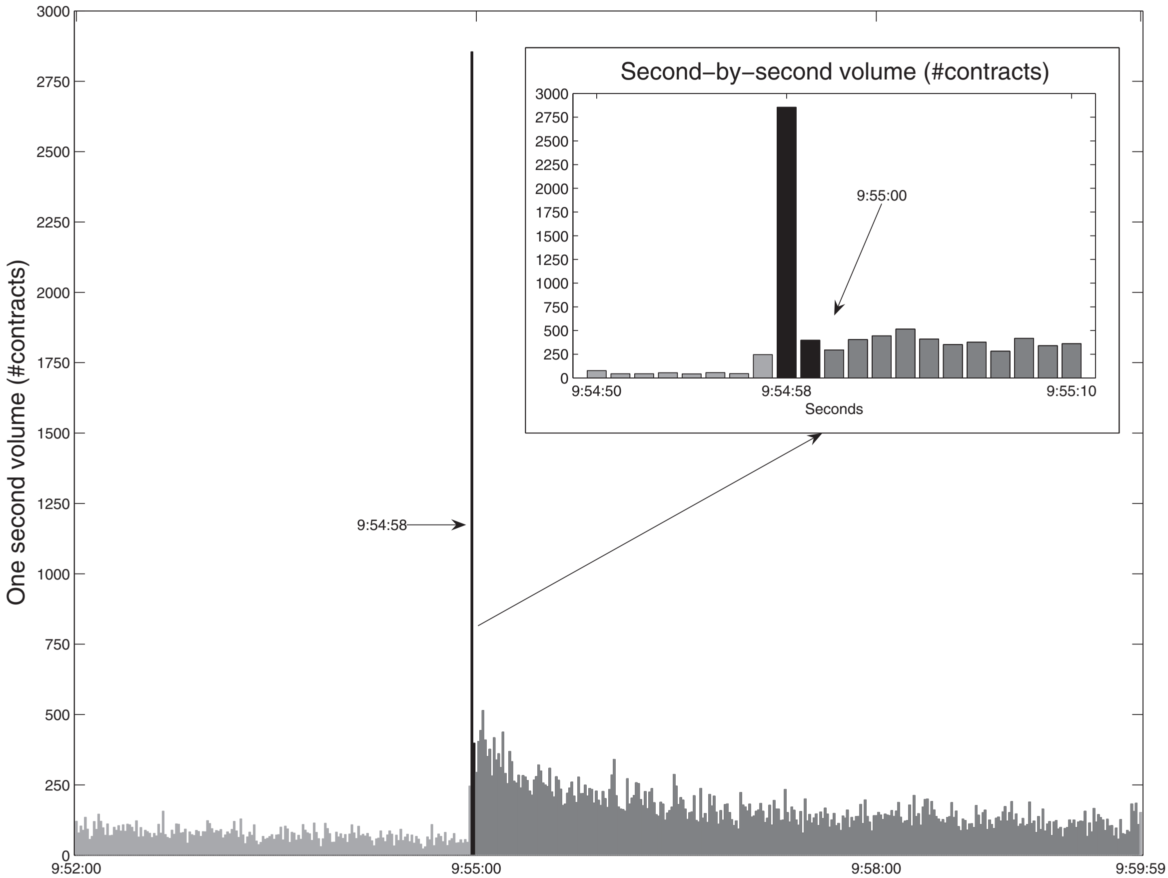


**Fig. 2.** Second-by-second trading volume of E-mini S&P 500 futures. We plot the average one-second trading volume of E-mini S&P 500, in number of contracts, over all preliminary ICS announcement days from January 2009 to June 2013. The trading volume for 9:54:58 and 9:54:59 is in black, the trading volume from 9:55:00 to 9:59:59 is in dark gray, and the trading volume from 9:52:00 to 9:54:57 is in light gray.

**Table 2**
Return and volume for sorted groups on ICS announcement days.

The Low, Med, and High groups contain the preliminary ICS announcement days with the bottom 40%, the middle 20%, and the top 40% index surprise (actual minus the median of economists' forecasts surveyed by Bloomberg) from January 2009 to June 2013. Returns are the average log returns for the respective time interval and are in basis points. Volume is the average 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. The *t*-statistics are reported in square brackets, and *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

| | Return | | | Volume | | | | |
|---|---|---|---|---|---|---|---|---|
| Period | Low | Med | High | Low | Med | High | L-M | H-M |
| #Days | 22 | 11 | 21 | | | | | |
| ICS surprise | – 4.74*** | – 0.61*** | 2.51*** | | | | | |
| | [ – 10.3] | [ – 2.71] | [7.60] | | | | | |
| 9:45:00 – 9:54:56 | 3.31 | – 1.25 | 3.97 | 95 | 109 | 93 | – 14 | – 17 |
| | [1.11] | [ - 0.38] | [0.95] | | | | [ – 1.25] | [ – 1.57] |
| 9:54:57 | – 1.95* | – 0.06 | 1.34* | 344 | 61 | 340 | 283 | 280 |
| | [ – 1.95] | [ – 0.10] | [1.67] | | | | [1.48] | [1.47] |
| 9:54:58 | – 10.40*** | – 0.10 | 6.92*** | 4639 | 886 | 2016 | 3753*** | 1130** |
| | [ – 8.24] | [ – 0.07] | [6.42] | | | | [4.39] | [2.01] |
| 9:54:59 | 0.12 | – 1.15* | – 0.32 | 631 | 137 | 297 | 494*** | 161** |
| | [0.24] | [ – 1.94] | [ – 0.89] | | | | [3.17] | [2.32] |
| 9:55:00 – 9:55:09 | – 0.35 | 1.82 | – 1.77 | 487 | 285 | 325 | 203** | 41 |
| | [ – 0.31] | [0.85] | [ – 1.16] | | | | [2.51] | [0.60] |

futures contracts exchanging hands during the single second of 9:54:58, around 33 times larger than the average trading volume of 87 contracts per second. 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 1,224. This roughly translates to a dollar trading volume of $175 million per second at 9:54:58, much higher than the average $5 million per second. In the following second, at 9:54:59, the trading volume drops quickly to 398 contracts, still around five times larger than 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.

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. Returns associated with early peek trading*

We sort the ICS announcement days from January 2009 to June 2013 into three groups based on the surprise of the index.[16] The low, med, and high groups contain the announcement days with the bottom 40%, the middle 20%, and the top 40% index surprise. As reported in Table 2, out of the 54 ICS announcement days, the average index surprise is negative (−4.74) on the 22 days in the Low group and positive (2.51) on the 21 days in the High group. For the Med group, the average index surprise is, though still negative statistically, quite small in magnitude (−0.61).

For the trading window before the early peek window, from 9:45:00 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 small in magnitude and only marginally statistically significant, implying that occasional early release at 9:54:57 is not common.

At 9:54:58, the one-second return is on average −10.4 bps on negative news days and 6.92 bps on positive news days, both strongly significant statistically. Given that the one-second return volatility is on average 1.53 bps for this sample period, these numbers are also large in economic significance. For the next second, at 9:54:59, there is no additional price drift. The average return is only 0.12 bps on negative news days and −0.32 bps on positive news days. In addition to the small magnitude, neither number is statistically significant. In other words, the price discovery happens in the first second of the early peek window, similar to our earlier observation that transaction volume is disproportionately concentrated at 9:54:58.

More importantly, there is no further price drift during the ten seconds after the broad release of ICS at 9:55:00. The average ten-second return from 9:55:00 to 9:55:09 is on average −0.35 bps on negative news days and −1.77 bps on positive news days. Neither number is statistically significantly different from zero. Given that the ten-second return volatility during this sample period is on average 3.52 bps, these numbers are also 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 first second of trading within the early peek window. For general 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 200 milliseconds of 9:54:48). This group of investors indeed loses the opportunity to

[16] Our goal is to group together announcements with similar information content. As long as the sorting variable reflects the information content of ICS, our results stay robust. We have tried alternative sorting variables such as the change of ICS and the market price movement at 9:54:58, the results are very similar.

**Table 3**
Trades within one second after the ICS release.
Return and volume for trades within one second after the ICS release. The preliminary ICS announcement days from January 2009 and June 2013 are sorted into Low (bottom 40%), Med (middle 20%), and High (top 40%) groups by index surprise (actual minus the median of economists' forecasts surveyed by Bloomberg). The exact ICS releasing time is approximated by the transaction time of the first trade in the second of 9:54:58. Trades within one second after the ICS releasing time are divided into five intervals, based on their transaction time in milliseconds. Returns are the average log returns for the respective time interval and are in basis points. Volume is the average number of contracts traded during the respective time interval. "L-M" and "H-M" indicate the difference in volume between the low and medium group, and the high and medium group, respectively. The *t*-statistics are reported in the square brackets, and *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

| | Return | | | Volume | | | | |
|---|---|---|---|---|---|---|---|---|
| Milliseconds | Low | Med | High | Low | Med | High | L-M | H-M |
| 0 – 199 | – 9.26*** | – 0.86 | 5.91*** | 3342 | 598 | 1472 | 2744*** | 874** |
| | [ – 7.77] | [ – 0.67] | [5.73] | | | | [4.58] | [2.04] |
| 200 – 399 | – 0.36 | 0.03 | 0.02 | 757 | 29 | 322 | 728** | 293** |
| | [ – 0.63] | [0.06] | [0.03] | | | | [2.26] | [2.22] |
| 400 – 599 | – 0.56 | – 0.27 | 0.60 | 277 | 8 | 117 | 269*** | 109*** |
| | [ – 1.40] | [ – 0.58] | [1.50] | | | | [2.72] | [2.61] |
| 600 – 799 | – 0.52 | – 0.03 | 0.19 | 159 | 25 | 70 | 134* | 45 |
| | [ – 1.19] | [ – 0.06] | [0.81] | | | | [1.79] | [1.39] |
| 800 – 999 | 0.41 | 0.21 | 0.07 | 162 | 254 | 46 | – 92 | – 208 |
| | [1.28] | [0.59] | [0.28] | | | | [ – 0.52] | [ – 1.23] |

profit from trading on ICS announcements. However, they are not disadvantaged by the informed high frequency traders in the sense that the price discovery process finishes within the early peek window through the trading amongst high frequency traders themselves. So as long as general investors stay out of the early peek window, they are not being picked off by informed traders.

After 9:55:09, there are further price fluctuations in all three groups, which are on average zero. These price swings are unlikely to be related to the early peek arrangement. By 9:55:00, ICS has already been widely available to all investors. Any price swings ten seconds 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. Thus, in the analysis to follow, we drop the time windows after ten seconds. (The results after 9:55:09 are available upon request.)

Consistent with our earlier discussion on abnormal trading, high-frequency trading in the early peek window is concentrated during the first second at 9:54:48. In Table 2, we see that the trading volume at 9:54:58 is on average 4,639 contracts per second for the Low group, 2,016 contracts for the High group, and 886 contracts for the Medium group. Not surprisingly, higher information content of ICS attracts more trading. Moreover, the effect is not symmetric, with negative news attracting 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 have reduced a lot compared with the volume in the first second at 9:54:58. More importantly, while there is still abnormally high trading volume during 9:54:59 compared to the average volume, such trading is no longer informationally relevant.

### 4.3. Zoom in on early peek window

Our analysis above shows that most of the early trading and all of the associated price impact happen during the first second of the early peek window at 9:54:58. Taking advantage of the millisecond timestamps of our transaction data, we now take a closer look at the tick-by-tick transactions after the ICS announcement at a finer time scale. At the time scale of milliseconds, the ICS news announcements are not all released at exactly 9:54:58.000. Due to the allowed error margin in the releasing time, the high frequency clients of Thomson Reuters can receive the ICS results as late as 9:54:58.500. Since we do not know the exact releasing time on each ICS announcement day, we approximate it using the transaction time of the first trade in the second of 9:54:58.[17] Across the 54 announcement days, the median transaction time for the first trade is 9:54:58.22, the lower 25% value is 9:54:58.04, and the upper 25% value is 9:54:58.67.

Using the first trade's transaction time as a proxy for the actual ICS releasing time, we then focus on all the trades in the following one second. Based on these trades' transaction time in milliseconds, we divide them into five intervals: the first interval contains all trades during the first 200 milliseconds after the ICS release; the last interval contains all the trades during the 800 to 999 milliseconds period after the ICS release.

As reported in Table 3, the average return over the trades in the first 200 milliseconds is −9.26 bps on negative news days. Compared with the average one-second return of −10.40 bps at 9:54:58 on negative news days, the trades in the first 200 milliseconds accomplish 89% of the one-second movement. Likewise, the average return over the first 200 milliseconds is 5.91 bps on positive news days, accounting for 85% of the total return in the full second. After the first 200 milliseconds, the returns of both groups during the remaining four time intervals are not only small in magnitudes but also not statistically significantly different from zero.

[17] Although the releasing time can be as early as 9:54:57.500, early releases before 9:54:58 are not common.

Similarly, trading activity is also overwhelmingly clustered around the first 200 milliseconds. On negative news days, associated with the trades in the first 200 milliseconds is a total trading volume of 3,342 contracts, which accounts for 72% of the total trading volume of 4,639 contracts during the entire second at 9:54:58. Similarly, on positive news days, the trades in the first 200 milliseconds have a total volume of 1,472 contracts, which is 73% of the one-second trading volume of 2,016 contracts at 9:54:58. Even for news days in the middle group when ICS does not have large informational content, the trades in the first 200 milliseconds have a total volume of 598 contracts, which is 67% of the one-second trading volume of 886 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 very fast. Within the first 200 milliseconds, 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 trades barely move the price, yet, they still account for about 25% 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 whereas the slower trades during the early peek window are traded at the adjusted market prices and do not enjoy any information advantage. Hence, a significant component of the early peek trading is in fact not information driven. Instead, they could 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.

## 5. Price discovery with early peek

So far our results show highly concentrated and informed trading during the early peek window and a very fast price discovery associated with this intense trading. What is less clear is how much of this fast price discovery is attributable to the early peek arrangement.

In this section, we formally test the hypothesis that the early peek arrangement facilitates faster price discovery. For this, we exploit two dimensions over which the early peek arrangement is absent. In cross section, we take advantage of other comparable indices whose announcements do not have the early peek arrangement. In time series, we make use of the fact that the early peek arrangement was abruptly suspended in July 2013 — breaking the sample into two periods, one with early peek arrangement and one without. Putting these two dimensions together, we have what the literature calls the "difference-in-difference" tests. In the language of this standard procedure, the ICS announcements are the treatment group, the announcements of other comparable indices function as the control group, and the suspension of the early peek arrangement is the exogenous event that breaks the sample into "before/after."

### 5.1. Measuring price impact

To gauge the speed of price discovery, we measure how market prices react to the news announcements of ICS and other macroeconomic indices over different time horizons. Suppose that the announcement happens on day $t$ at a prespecified time, typically at the beginning of a second. Let $\Delta_t$ denote the index surprise as measured by the difference between the actual release on the announcement day and the median of the professional forecast surveyed by Bloomberg and $R_t$ be the return of E-mini S&P 500 from a given time interval, in seconds, after the news release. We perform the following regression

$$R_t = a + b \times \Delta_t + \varepsilon_t\,. \tag{1}$$

To make the regression comparable across different indices, we further normalize the index surprises by their respective standard deviations.[18] So for a given macroeconomic index, the regression coefficient $b$ measures the average response in market return for a one standard deviation shock to the index.

To measure price drift over different horizons, we perform the regression specified in Eq. (1) by considering returns, $R_t$, over different time intervals. In choosing the time intervals, we take into account the fact that, for most indices, the corresponding market response happens within a few seconds. Because of this, we focus mostly on the first ten seconds after the announcements and split this ten-second window into the following three periods:

- 0s: The initial one second right after the announcement. Hence, in the regression specified by Eq. (1), the initial one-second response is measured using the market return over the first second of the news release. For example, if the news is released at the beginning of 10:00:00, the initial one-second return, which can be denoted by $R_t(0s)$, is calculated using the last transaction prices at the end of 9:59:59 and 10:00:00, respectively. We use "0s" to label this time horizon because it occurs during the initial second of the news release.
- 1–4s: Following the initial second 0s, we label the next four seconds by 1 – 4 s. To measure the price impact over the next four seconds, we use the cumulative four-second return from the end of the first second to the end of the fifth second, which can be denoted by $R_t(1-4s)$, as the market return in Eq. (1).
- 5–9s: We label the last five seconds by 5 – 9 s. Similarly, to measure the price impact over the last five seconds, we use the cumulative five-second return from the end of the fifth second to the end of the 10th second, i.e., $R_t(5-9s)$.

As can be seen in our preliminary analysis, for ICS during the early peek period, the only time horizon that matters is the first second after the news release. In fact, the price discovery happens in less than a few hundred milliseconds for ICS during early peek. As such, the split could

[18] We use the sample standard deviation over a longer sample period, from May 1999 to June 2016, to normalize the surprises for each index.

be the first second vs. the rest. But as it becomes clear later, for other indices and for the post early peek period, there is continued price drift for at least two or three seconds after the announcements. This further price drift is exactly what we would like to capture. Thus, we group the next four seconds (1 – 4 s) to allow this price drift to fully play itself out, as well as to reduce the noise associated with the second-by-second returns. Alternative specifications testing the drift over the horizon of the next two seconds (1 – 2 s) or the next three seconds (1 – 3 s) generate similar difference-in-difference results.

The regression specification in Eq. (1) has the advantage that it also allows us to control for other factors. For example, in our difference-in-difference tests, we have also included controls such as the market implied volatility (Chicago Board Options Exchange VIX) and E-mini S&P 500 futures return and trading volume before the index announcement.[19] They do not have much influence on our results. This is not surprising given that the over first few seconds after each news announcement, the most important factor moving the market returns is the news itself. Thus, we stay with the simple specification in presenting our results.

With these notations in place, we can now take a look at the price impact measurements reported in Table 4. For example, during the early peek period, which spans from January 2009 to June 2013, the price impact coefficient for ICS is measured over three different time horizons. Over the first second after the announcement (labeled by 0 s), a one standard deviation shock in ICS has a price impact of 8.26 basis points with a $t$-stat of 11.60. Given that the average volatility for a one-second return of E-mini S&P 500 is around 1.5 basis points during the early peek period, this price impact is economically important. Over the next four seconds (labeled by 1 – 4 s), the price impact decreases to −0.44 basis points, economically small and statistically insignificant. Over the last five seconds (labeled by 5 – 9 s), this price impact coefficient is −0.29 basis points with a $t$-stat of -0.42. Overall, this set of numbers is consistent with the pattern captured by our preliminary analysis: for ICS during early peek, the price discovery takes less than one second; outside of this one-second window, there is no price drift. As mentioned earlier, to attribute this fast price discovery to the early peek arrangement, we need to exploit dimensions over which early peek is absent.

### 5.2. The cross-sectional dimension

Along this dimension, we take advantage of the fact that ICS is one of the very few indices whose announcements have the early peek arrangement from January 2009 to June 2013. For this same time period, we look for similar indices that are comparable to ICS but do not have the early peek arrangement.

#### 5.2.1. ISM indices as controls

We find the surveys published by the Institute for Supply Management (ISM) to be suitable candidates. We focus on two ISM surveys: ISM non-manufacturing (ISMN) and ISM manufacturing (ISMM). The ISM non-manufacturing index is based on the surveys of more than 400 managers of non-manufacturing firms and is released on the sixth business day of every month; the ISM manufacturing index is based on the surveys of more than 300 managers of manufacturing firms and is released on the first business day of every month.

Putting aside the early peek arrangement, which is unique for ICS, there are several important similarities between these indices. First, like ICS, both the ISM non-manufacturing and the manufacturing indices are widely tracked economic indicators and contain information that can significantly move the market. Second, similar to ICS, the ISM surveys are collected and compiled by an organization that is nonprofit and nongovernmental. Third, on their respective announcement days, ISMN and ISMM are released at 10:00:00 a.m. EST to the public via the website of ISM and Business Wire. Unlike the macroeconomic indicators collected and compiled by government agencies (such as the Nonfarm Payrolls), which are usually announced at 8:30:00 a.m. EST, the 10:00:00 a.m. release time of the ISM indices has the advantage that it is close to the release time of ICS and is within the regular trading hours of the futures market. Finally, like ICS, both of the ISM indices are available in machine readable format. Thomson Reuters, through its News Feed Direct service, sends the index numbers in a machine readable format to its high-speed subscribers. As a result, the outcome of the ISM surveys can be accessed by high-speed traders immediately after their release.

Although available through the machine readable format via Thomson Reuters, the release arrangement of the ISM indices differs from that of ICS in that all investors, including both the high-speed traders and the general investors, receive the ISM reading at the same time. By contrast, the high-speed traders with early peek arrangement with Thomson Reuters receive the ICS index two seconds earlier than the general investors. This important difference, along with all of the similarities between ICS and ISM, makes the ISM indices ideal controls. We will use the ISMN and ISMM separately as controls for the cross-sectional comparison. Moreover, we can compare the price discovery of ISMN and ISMM and use the ISMN/ISMM pair as a placebo test to our formal difference-in-difference tests between ICS vs. ISMN, as well as ICS vs. ISMM.

#### 5.2.2. Testing the cross-sectional difference in price discovery

Using the ISM indices as controls, we focus on the same time period during which the early peek arrangement is in place for ICS and investigate the potential differences in the speed of price discovery between the ISM indices and ICS.

To formally test the cross-sectional difference, we adopt the standard procedure by running a pooled regression. Specifically, suppose there are two indices, Index 1 and 2. Running two separate regressions according to the specification in Eq. (1) would yield two regression coefficients,

[19] More specifically, we run the following regression $R_t = a + b \times \Delta_t + controls_t + \varepsilon_t$, where the controls include the closing value of CBOE VIX index on the previous trading day before the index announcement, return and volume of the most active E-mini S&P 500 futures contract in a five-minute trading window before the index announcement. With these control variables, the regression coefficient $b$ remains very close to the value we report in the paper, which is based on regression $R_t = a + b \times \Delta_t + \varepsilon_t$.

**Table 4**
Difference-in-difference tests of price impact surrounding news announcements.

The estimated coefficients $b$ of the regressions, $R_t = a + b \times \Delta_t + \varepsilon_t$, are compared across indices and time periods. The early peek period is from January 2009 to June 2013, and the post period is from July 2013 to June 2016. The return $R$ is the return over the first second after the news release for the set of results labeled as "0s"; the return $R$ is the cumulative four-second return from the end of the first second to the end of the fifth second after the news release for the set of results labeled as "1 – 4s"; the return $R$ is the cumulative five-second return from the end of the fifth second to the end of the tenth second after the news release for the set of results labeled as "5 – 9s". The index surprise $\Delta$ of the ICS/ISMM/ISMN is calculated as the difference between the actual release and the median of Bloomberg economists' forecasts, normalized by its standard deviation. The $t$-statistics are reported in the square brackets, and *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

*Panel A: ICS preliminary (ICS) vs. ISM Non-Manufacturing (ISMN)*

| | 0 s | | | 1 – 4 s | | | 5 – 9 s | | |
|---|---|---|---|---|---|---|---|---|---|
| | During | Post | Diff = Post-during | During | Post | Diff = Post-during | During | Post | Diff = Post-during |
| ICS | 8.26*** | 1.51*** | −6.76*** | −0.44 | 0.87** | 1.31** | −0.29 | 0.32 | 0.61 |
| | [11.60] | [4.43] | [−8.56] | [−0.86] | [2.09] | [1.98] | [−0.42] | [1.36] | [0.85] |
| ISMN | 8.45*** | 1.34*** | −7.12*** | 3.07*** | 1.19** | −1.88 | −0.98 | −0.33 | 0.65 |
| | [8.47] | [3.05] | [−6.53] | [2.68] | [2.16] | [−1.48] | [−1.15] | [−1.02] | [0.71] |
| Diff=ICS-ISMN | −0.19 | 0.17 | 0.36 | −3.51*** | −0.32 | 3.19** | 0.69 | 0.65 | −0.04 |
| | [−0.16] | [0.30] | [0.27] | [−2.80] | [−0.46] | [2.23] | [0.64] | [1.63] | [−0.04] |

*Panel B: ICS preliminary (ICS) vs. ISM Manufacturing (ISMM)*

| | 0 s | | | 1 – 4 s | | | 5 – 9 s | | |
|---|---|---|---|---|---|---|---|---|---|
| | During | Post | Diff = Post-during | During | Post | Diff = Post-during | During | Post | Diff = Post-during |
| ICS | 8.26*** | 1.51*** | −6.76*** | −0.44 | 0.87** | 1.31** | −0.29 | 0.32 | 0.61 |
| | [11.60] | [4.43] | [−8.56] | [−0.86] | [2.09] | [1.98] | [−0.42] | [1.36] | [0.85] |
| ISMM | 9.90*** | 2.57*** | −7.32*** | 3.11*** | 1.58*** | −1.52 | 1.04 | 0.68* | −0.36 |
| | [7.81] | [4.18] | [−5.20] | [3.03] | [4.58] | [−1.41] | [1.02] | [1.65] | [−0.33] |
| Diff=ICS-ISMM | −1.63 | −1.07 | 0.57 | −3.55*** | −0.71 | 2.83** | −1.33 | −0.36 | 0.97 |
| | [−1.12] | [−1.52] | [0.35] | [−3.09] | [−1.32] | [2.23] | [−1.09] | [−0.76] | [0.74] |

*Panel C: ISM Non-Manufacturing (ISMN) vs. ISM Manufacturing (ISMM)*

| | 0 s | | | 1 – 4 s | | | 5 – 9 s | | |
|---|---|---|---|---|---|---|---|---|---|
| | During | Post | Diff = Post-during | During | Post | Diff = Post-during | During | Post | Diff = Post-during |
| ISMN | 8.45*** | 1.34*** | −7.12*** | 3.07*** | 1.19** | −1.88 | −0.98 | −0.33 | 0.65 |
| | [8.47] | [3.05] | [−6.53] | [2.68] | [2.16] | [−1.48] | [−1.15] | [−1.02] | [0.71] |
| ISMM | 9.90*** | 2.57*** | −7.32*** | 3.11*** | 1.58*** | −1.52 | 1.04 | 0.68* | −0.36 |
| | [7.81] | [4.18] | [−5.20] | [3.03] | [4.58] | [−1.41] | [1.02] | [1.65] | [−0.33] |
| Diff=ISMN-ISMM | −1.44 | −1.24 | 0.21 | −0.04 | −0.39 | −0.35 | −2.02 | −1.01* | 1.01 |
| | [−0.89] | [−1.63] | [0.12] | [−0.03] | [−0.61] | [−0.21] | [−1.52] | [−1.92] | [0.71] |

one for each index. Alternatively, we can pool the two samples together, stack them up, and run the following pooled regression:

$$R_t^i = a_0 + a_1 \times \mathbb{1}_{\{i \in 1\}} + b_0 \times \Delta_t^i + b_1 \times \mathbb{1}_{\{i \in 1\}} \times \Delta_t^i + \varepsilon_t^i, \quad (2)$$

where $i = 1$ for Index 1, $i = 2$ for Index 2, and the index dummy $\mathbb{1}_{\{i \in 1\}}$ equals one if $i = 1$ and zero otherwise. In this setup, the coefficient $b_0 + b_1$ captures the market impact of Index 1, and the coefficient $b_0$ captures the market impact of Index 2. Effectively, this pooled regression reproduces the respective regression coefficients for the unpooled regressions.[20] But a useful by-product of this pooled regression is that it allows us to test the difference $b_1$, between the regression coefficients for Index 1 and 2. Of course, $a_1$ captures the index fixed effects.

[20] By construction, this pooled regression recovers the original unpooled regression coefficients. But their $t$-stats could be distorted if there is a substantial difference between the residual variances of two un-pooled regressions. We use the standard procedure by weighting the observations by the inverse of their respective residual variances, estimated using the individual unpooled regression specified in Eq. (1).

We focus first on the ISM non-manufacturing index, labeled as ISMN in Table 4, for the time period when the early peek arrangement is in place for ICS. Over the first second (0 s) after the announcements, a one standard deviation shock in ISMN has a price impact of 8.45 basis points, comparable to the 8.26 basis points for ICS. This difference in price impact between ICS and ISMN is formally tested in Table 4. It is small in magnitude (−0.19 basis points) and statistically insignificant. In other words, both ICS and ISMN contain market-moving information, and the market responds to the information promptly during the first second of the announcements. As measured by the market impact over the first second, the informational content of these two indices is similar in magnitude.

What happens over the next four seconds (1 – 4 s) is more interesting. As reported in Table 4, the market impact for ISMN remains positive and significant. A one standard deviation shock in ISMN has a price impact of 3.07 basis points, which is 36% of the initial one-second response and it is statistically significant. This pattern of sizable price drift outside of the initial one-second window is in direct contrast to that of ICS. As a result, the cross-sectional difference between the two price impact coefficients, ICS minus ISMN, is negative (−3.51 basis points) and statistically significant (with a $t$-stat of −2.80). Recall that these two indices are comparable in many dimensions. Moreover, they have similar magnitudes of price impact during the first second of the announcements. Nevertheless, outside of the one-second window, there is further price drift for ISMN but none for ICS. Overall, this evidence provides strong support of the hypothesis that the early peek arrangement, through its tiered information release, facilitates faster price discovery.

Over the last five seconds (5 – 9 s), there is no more price drift for ISMN, and there is no significant cross-sectional difference between ISMN and ICS. In other words, by then, the informational shock contained in either index has already been incorporated into prices, and the market goes back to its normal state.

In addition to ISMN, we use the comparison between the ISM manufacturing index (ISMM) and ICS functions as an additional support of the cross-sectional evidence. As reported in Table 4, over the first second after the announcements, a one standard deviation shock in ISMM has a price impact of 9.90 basis points, which is slightly larger than the 8.26 basis points for ICS. But as shown in the cross-sectional difference test, this difference in price impact is statistically insignificant. Over the next four seconds, however, the price impact for ISMM remains positive and statistically significant: it is 3.11 basis points, about 31% of its price impact over the initial one-second window. The cross-sectional difference test over this four-second window is very similar to that for the ISMN/ICS pair, providing further support of the hypothesis that the early peek arrangement improves price discovery.

Finally, taking advantage of the ISMN and ISMM pair, we use them as a placebo test. Overall, there is no significant difference between the price impact for ISMN and ISMM. Over the first second of the announcements, both indices have similar magnitudes in their price impact, with ISMM slightly larger than ISMN, although the difference is not statistically significant. Over the next four seconds, both indices exhibit further price drift, again with ISMM slightly larger than ISMN, although the difference is not statistically significant. Over the last five seconds, the information content dissipates for both indices.

Overall, our cross-sectional evidence is strongly supportive of the hypothesis that because of the early peek arrangement, the price discovery for ICS is significantly faster than that of ISMN and ISMM. And the difference in the speed of price discovery is the strongest over the four-second time window immediately following the initial one-second of price response. In addition, it is unlikely that this cross-sectional difference in the speed of price discovery is driven by the cross-sectional difference in price impact. In particular, the initial one-second price impact for ISMM is larger in magnitude than that of ICS and ISMN. Nevertheless, we find significant price drift over the 1 – 4 s time horizon for both ISMM and ISMN, but none for ICS.[21] Later, in our difference-in-difference tests, we will be able to address this issue more cleanly and conclusively. In fact, any intrinsic cross-sectional differences (other than the early peek arrangement) are present both before and after the suspension of early peek. As a result, our difference-in-difference tests are robust to such intrinsic cross-sectional differences other than the early peek arrangement.

### 5.3. The time-series dimension

Along the time-series dimension, we make use of the fact that the early peek arrangement was abruptly suspended in July 2013. As mentioned earlier in the paper, the early peek arrangement started around 2007, but it was not until June 2013 when this practice started to attract attention from the press. It was quickly followed by a review from the office of the New York Attorney General. In July 2013, less than one month after the initial media coverage, Thomson Reuters suspended the program. The sudden and exogenous nature of this event offers us a rather clean setting to uniquely isolate the impact of the early peek arrangement. From before to after this sudden event, the only difference is the early peek arrangement.[22]

#### 5.3.1. The post early peek period

The post early peek period begins on July 1, 2013 and is updated to June 3, 2016 in our paper. Over this period, the number of monthly announcements are 35 for ICS preliminary, 36 for ISMN, and 36 for ISMM. Compared with the period during the early peek, when all three indices each have 54 announcements, this sample size is smaller but long enough to give us confidence in our test results.[23]

As reported in Table 4, for the post early peek period, a one standard deviation shock in ICS has a price impact of 1.51 basis points over the first second of the news release. This price impact is statistically significant with a $t$-stat of 4.43. The average one-second return volatility for the E-mini S&P 500 futures is about one basis point in the post early peek period. As such, the price impact of 1.51 basis points remains economically important. Nevertheless, compared with the price impact of 8.26 basis points dur-

[21] In an early draft of the paper, we also included the announcements of Nonfarm Payrolls in our cross-sectional test. We find that its price discovery is of the same speed as that of the ISM indices, although its price impact is significantly larger than ICS or the ISM indices.

[22] In addition to its suspension, the initial introduction of the early peek arrangement could also be used as an event. But it is not ideal for two reasons. First, the event is not a truly exogenous one. From 1999 to 2006, the presence of high-speed trading has increased quite steadily, and the early peek arrangement by Thomson Reuters was to some extent a response to this trend. As such, price discovery could be faster after the installation of the early peek arrangement not because of early peek itself but simply due to the increasing presence of high frequency trading. Second, prior to the early peek arrangement, we cannot identify the exact time when the University of Michigan releases the ICS results to its subscribers. Even the release time to the general public is difficult for us to pin down for this sample period.

[23] Three of the announcements occurred on nontrading days. So we have 34 observations for ICS in the post period and 53 observations for ISMN and ISMM, respectively, during the early peek period. As a side note, our first draft was completed soon after the suspension of the early peek arrangement. At that time, the sample size was relatively short for the results to be very robust. With the lapse of time, we now have a sample that is long enough to have meaningful results.

ing early peek, there is a significant reduction, and the new price impact is only 18.3% of the old level.

This shift in market impact is not only specific to ICS. As shown in Table 4, a one standard deviation shock in ISMN has a price impact of 1.34 bps, 15.9% of its old level; for ISMM, the price impact is now 2.57 basis points, 26% of its old level. Part of the reduction in price impact is related to the fact that the markets are calmer and less volatile in the post period. For example, the one-second return volatility decreases from around 1.6 basis points during the early peek period to around 1 basis point in the post period. But this cannot explain all of the reduction. It should also be mentioned that this reduction in price impact is not because the indices are less informative over the post period. In fact, the average size of the index surprises remains stable across time.

To further understand what might have caused this reduction in price impact, we take a closer look at the trading activities surrounding the announcements. It should first be noted that, as an overall market trend, the average trading volume in the post period is significantly lower. This phenomenon of reduced trading volume happened in both equity index futures and cash markets after the 2008 – 2009 financial crisis. As shown in Table 1, on ICS preliminary announcement days, the average trading volume at the first second after the ICS preliminary announcements is 2,855 contracts during the early peek period, and is reduced to 426 contracts in the post period. This reduction in trading volume also occurs on ISM announcement days, from 2,247 to 527 contracts for ISMN and from 3,792 contracts to 833 contracts for ISMM.

For our investigation, it is important that this pattern of reduction in price impact and trading activity happened across the board for all three indices.[24] As long as this time-series shift affects both the treatment (ICS) and the controls (ISMN or ISMM), the cross-sectional difference within each time period can take out the time-specific effects. As a result, our final difference-in-difference test should be robust to the time-series shift.

#### 5.3.2. Price drift for ICS before and after

Against this backdrop of across the board reduction in trading and price impact, what happens over the next four seconds (1 – 4 s) after the announcement is interesting and important for our study. More specifically, we now observe continued price drift for ICS: over the next four seconds, a one standard deviation shock in ICS has a price impact of 0.87 basis points with a $t$-stat of 2.09. Recall that during early peek, the corresponding price impact was -0.44 basis points with a $t$-stat of $-0.86$. This emergence of further price drift for ICS in the post early peek period is at the heart of our result. And the fact that it happens in an environment of weakening price impact for all indices in the post period is all the more revealing. For example, the price impact over the four-second window decreases from 3.07 basis points to 1.19 basis points for ISMN, and from 3.11 basis points to 1.58 basis points for ISMM.

We can now formally test the time-series difference between the price impact. Fixing on the announcements on one index, say, ICS, we run the following regression by pooling the two time periods together,

$$R_t = a_0 + a_1 \times \mathbb{1}_{\{t\in post\}} + b_0 \times \Delta_t + b_2 \times \mathbb{1}_{\{t\in post\}} \times \Delta_t + \varepsilon_t, \tag{3}$$

where *post* denotes the post early peek period, and the index dummy $\mathbb{1}_{\{t\in post\}}$ equals one if the announcement falls in the post period, i.e., $t \in post$ and zero otherwise. Effectively, $b_0 + b_2$ captures the price impact in the post early peek period, $b_0$ captures the price impact during the early peek period, and $b_2$ measures the time-series difference in price impact.[25]

As discussed earlier, there is a clear marketwide reduction in price impact after the suspension of the early peek arrangement. So, as shown in Table 4, testing the time-series difference over the first second of the news release basically reconfirms this observation. It is the further price drift after the initial second that is important for our results. For ICS, over the next four seconds (1 – 4 s), the price impact is $-0.44$ basis points before and 0.87 basis points after. As reported in Table 4, the difference is 1.31 basis points and is statistically significant, indicating a significant difference in further price drift before and after the suspension of early peek. Our results clearly show an emergence of further price drift for ICS in the post early peek period, which was absent during the early peek period. This provides a strong support for the hypothesis that the early peek arrangement facilitates faster price discovery.

### 5.4. The difference-in-difference tests

To cleanly isolate the effect of early peek on price discovery, we take advantage of the difference-in-difference tests. Along the time-series dimension, the suspension of the early peek arrangement for ICS breaks time into before and after. Along the cross-sectional dimension, the presence of the early peek arrangement for ICS before the suspension sets it apart from its controls (ISMN or ISMM). Effectively, the overall dimension can be labeled by a $2 \times 2$ matrix of treatment/control and before/after. Among the four cells consisting of this $2 \times 2$ matrix, only one cell, ICS during early peek, has the early peek arrangement in place. All three other cells share the commonality that there is no early peek arrangement. Compared with our earlier tests along the cross-sectional or time-series dimensions, the difference-in-difference tests offer a more robust way to investigate the effect of early peek on price discovery.

#### 5.4.1. Measuring the difference-in-difference

To formally perform the difference-in-difference test, we run the following pooled regression,

$$R_t^i = a_0 + a_1 \times \mathbb{1}_{\{i=1\}} + a_2 \times \mathbb{1}_{\{t\in post\}} + a_3 \times \mathbb{1}_{\{i=1\}} \times \mathbb{1}_{\{t\in post\}}$$

[24] In addition to ISMN and ISMM, we also find lower trading activity and smaller market response for the Nonfarm Payrolls announcements in the post peek period.

[25] As discussed in the cross-sectional test, the $t$-stat of this pooled regression could be distorted if there is a substantial difference between the residual variances of the two unpooled regressions. We correct our $t$-stat to make it robust to this potential distortion.

$$+ b_0 \times \Delta_t^i + b_1 \times \mathbb{1}_{\{i=1\}} \times \Delta_t^i + b_2 \times \mathbb{1}_{\{t\in post\}} \times \Delta_t^i + b_3 \times \mathbb{1}_{\{i=1\}} \times \mathbb{1}_{\{t\in post\}} \times \Delta_t^i + \varepsilon_t^i, \quad (4)$$

where the index dummy $\mathbb{1}_{\{i=1\}}$ is as specified in the cross-sectional test of Eq. (2), and the time dummy $\mathbb{1}_{\{t\in post\}}$ is as specified in the time-series test of Eq. (3). Recall that in the cross-sectional test, the two samples of treatment and control are pooled together into one regression, and the cross-sectional difference $b_1$ is measured via the interaction term between the index dummy and the index surprise. In the time-series test, the two time periods of before and after are pooled together into one regression, and the time-series difference $b_2$ is measured via the interaction term between the time dummy and the index surprise. Now in the difference-in-difference regression, the four samples of treatment/control and before/after are pooled into one, and the difference-in-difference $b_3$ is measured via the triple interaction term of the index dummy, time dummy, and the index surprise. Again, we correct the $t$-stat of the pooled regression so that it is robust to the differences in the residual variances across the four unpooled samples.

Given the $2 \times 2$ dimension, it is more intuitive to list the four price impact coefficients separately and correspond them to the regression coefficients in Eq. (4):

| | During | Post | Diff = Post-during |
|---|---|---|---|
| Index 1 | $b_0 + b_1$ | $b_0 + b_1 + b_2 + b_3$ | $b_2 + b_3$ |
| Index 2 | $b_0$ | $b_0 + b_2$ | $b_2$ |
| Diff=1 – 2 | $b_1$ | $b1 + b_3$ | $b_3$ |

Table 4 reports this $2 \times 2$ matrix of price impact coefficients along with the test statistics for the cross-sectional difference, time-series difference, and the difference-in-difference. The results are reported over three time horizons and for the pairs of ICS/ISMN, ICS/ISMM, and ISMN/ISMM.

### 5.4.2. Time horizons: (0 s) and (5 – 9 s)

Focusing first on the pair of ICS and ISMN, over the first second (0 s) after the news release, the price impact measures the initial market response. Across the treatment (ICS) and control (ISMN), we see similar price impact. Across the two time periods, we see a weaker price impact in the post period. As shown in Table 4, performing a difference-in-difference test over this time horizon reveals a statistically insignificant test result, indicating no substantial difference in price impact during the initial market response.

It is important to point out that, although the final difference-in-difference test reveals no significant difference in price impact, the time-series differences are significant for both ICS and ISMN, respectively, due to the weakened price impact in the post period. In this sense, the difference-in-difference test is a more robust test, with ISMN acting as a control. In the presence of any time-series variations, the time-series difference test might not be robust, but the difference-in-difference test is, as long as the time-series variations affect both the treatment and the control equally.

Jumping ahead to the last five seconds (5 – 9 s), we see a picture of what happens toward the end of the price discovery. Overall, there is no more price impact and the market goes back to its normal state. Again, performing a diff-in-diff test over this time horizon indicates no substantial difference in price impact for this time horizon.

### 5.4.3. Time horizon: (1 – 4 s)

Now let's focus on the most important horizon: the four seconds (1 – 4 s) after the initial response. Indeed, performing a difference-in-difference test over this time horizon reveals a statistically significant test result, indicating meaningful difference in price impact, and importantly, this difference in price discovery can be attributed uniquely to the presence and absence of the early peek arrangement.

To understand the final test result, it is instructive to first look at its building blocks — the $2 \times 2$ matrix of price impact:

| Price impact over (1 – 4 s) | | | Early peek arrangement? | | |
|---|---|---|---|---|---|
| | During | Post | | During | Post |
| ICS | −0.44 | **0.87** | ICS | Yes | No |
| ISMN | **3.07** | **1.19** | ISMN | No | No |

where measurements with statistical significance are reported in bold. As we can see, in this $2 \times 2$ matrix, ICS during early peek is the only cell with a slightly negative number and is statistically insignificant. All of the other three cells have positive and statistically significant price impact coefficients, indicating further price discovery after the initial second. This pattern maps exactly to the presence and absence of the early peek arrangement. In the presence of the early peek arrangement, there is no further price drift; in the absence of the early peek arrangement, there is further price drift. This is perhaps the most direct and intuitive way to understand the essence of our results.

To formally test the connection between price discovery and the early peek arrangement, we focus on the difference-in-difference test, constructed using the above $2 \times 2$ matrix of price impact coefficients as building blocks,

$$\begin{aligned} \text{Diff-in-Diff} &= [\text{ICS Post} - \text{ICS During}] \\ &\quad - [\text{ISMN Post} - \text{ISMN During}] \\ &= [0.87 - (-0.44)] - [1.19 - 3.07] \\ &= 3.19. \end{aligned}$$

As shown in Table 4, the diff-in-diff test is statistically significant with a $t$-stat of 2.23.

This final difference-in-difference test can be viewed from two angles. Focusing first on the time-series dimension, we see a positive and statistically significant time-series difference for ICS: $0.87-(-0.44) = 1.31$ basis points, indicating significant price drift after the suspension of the early peek arrangement. This evidence is consistent with our hypothesis that the presence of early peek improves price discovery. But it is possible that some time-series shift in the overall market condition makes the price discovery slower in the post period, thus causing further price drift. To address this concern, we take into account the time-series difference for ISMN: $1.19–3.07 = -1.88$, which is negative, but not statistically significant. In other words, relative to the time-series change in the control group, the increased price drift for ICS remains significant. In fact, the increased price drift happens in an environment in which the price impact weakens across the board for all indices.

Another way to view the difference-in-difference result is to focus first on the cross-sectional dimension. During the early peek period, we see a negative and statistically significant cross-sectional difference: $-0.44–3.07 = -3.51$ basis points, indicating significant difference in price drift between the treatment and the control. This evidence is consistent with our hypothesis that the presence of early peek improves price discovery. But it is possible that the control has slightly more price impact and therefore takes longer for the information to be absorbed into market prices. To address this concern, we take into account the cross-sectional difference after the suspension of the early peek: $0.87–1.19 = -0.32$, which is not statistically significant. In other words, in the post period, when there is no early peek arrangement for either the treatment or the control, there is no longer any significant difference in price drift between the treatment and control. The final difference-in-difference takes this into account and attributes the difference in price impact uniquely to the early peek arrangement.

Repeating the difference-in-difference tests for ICS vs. ISMM gives us a very similar set of results. Again, at the heart of our results is the lack of price drift of ICS during the early peek, the emergence of price drift of ICS after the suspension of the early peek, and the presence of drift for ISMN (or ISMM) during and post early peek. Not surprisingly, running the difference-in-difference tests for ISMN vs. ISMM yields no results because the presence of price drift is always there, before and after, for both indices.

## 6. The impact of early peek on volatility

Our results thus far focus on how the early peek arrangement could help facilitate faster price discovery. In this section, we take one step further and ask, in addition to improving its speed, can early peek also help improve the precision of the price discovery process? We do so by analyzing the impact of early peek on return volatility.

Returns and volatility help reflect two separate aspects of the market behavior. While market returns capture the average speed of price discovery, volatility reflects the precision or quality of the price discovery process. Indeed, a faster speed does not automatically result in more precision. In a price discovery process that is relatively precise, price movements would be driven more by the underlying information and less by noise. For the same amount of underlying information, this implies a faster resolution in uncertainty. We therefore expect to see the return volatility settle down more quickly to its steady state and a lower level of overall volatility during the price formation process.

For market participants, a more precise price discovery process, with early resolution of uncertainty, means better market liquidity and less deadweight cost involving execution risk and liquidity cost. As such, understanding the impact of volatility is just as important and could shed light on the additional benefits associated with the early peek arrangement.

### 6.1. Measuring volatility

On each announcement day, we calculate the second-by-second return volatility of E-mini S&P 500 futures using transaction-level data. Specifically, let's suppose that the news release happens at the beginning of a second, say 10:00:00. For this initial second, we calculate the one-second volatility by using all transaction prices occurring during this second. Let $P_1, P_2, \ldots, P_N$ be the sequence of transaction prices observed during the one second between the end of 9:59:59 and the end of 10:00:00, with $P_1$ as the last transaction price at 9:59:59 and $P_N$ as the last transaction price at 10:00:00. The one-second variance is calculated by $\sum_{i=2}^{N} (\ln P_i - \ln P_{i-1})^2$, and the one-second volatility is the square root of the variance. We repeat the same calculation for each of the seconds surrounding the news release.

To make the volatility measure comparable across different announcement days, we further scale this one-second volatility by the one-second benchmark volatility, which is the square root of the average one-second variance over a four-minute window, ten minutes after the release time on the same announcement day.

Effectively, by having the scaled volatility, we can capture the deviations of volatility away from the steady state and compare them across different announcement days. Focusing on the early peek period, from January 2009 through June 2013, Fig. 3 reports the second-by-second scaled volatility averaged across all ICS preliminary announcements. Also plotted are the corresponding 95% confidence intervals of the volatility measures. As we can see, associated with the new releases are the heightened levels of volatility. During the initial one-second window after the news release (labeled by 0 second on the $x$-axis), the average volatility is 5.99 times the normal level. After the news event, the volatility gradually decays to its steady state.[26]

For comparison, we also plot the scaled volatility for the ISM indices in the same figure. Immediately after the news release, the one-second scaled volatility is 5.86 for ISMN, about the same level as that for ICS, and 7.69 for ISMM, slightly larger than that for ICS and ISMN. For all three indices, we observe the same pattern: the initial heightened volatility due to the news release and the eventual decay back to the steady state. There is, however, an interesting difference in how fast the decay takes place during the first few seconds after the news release. In particular, although the initial one-second responses are of similar orders of magnitude for ICS and ISMN, the resolution of uncertainty, as revealed in Fig. 3, is faster for ICS

[26] As can be seen in Fig. 3, on average, it takes about 60–90 seconds for the volatility to settle down to its normal level. In our price impact measures, the horizon is much shorter. The effect of the news release can be captured in returns in less than ten seconds. Afterwards, the price impact measures are no longer statistically significant. It is well known that expected returns are difficult to measure with precision because returns are noisy. By contrast, volatilities can be measured with much better precision.

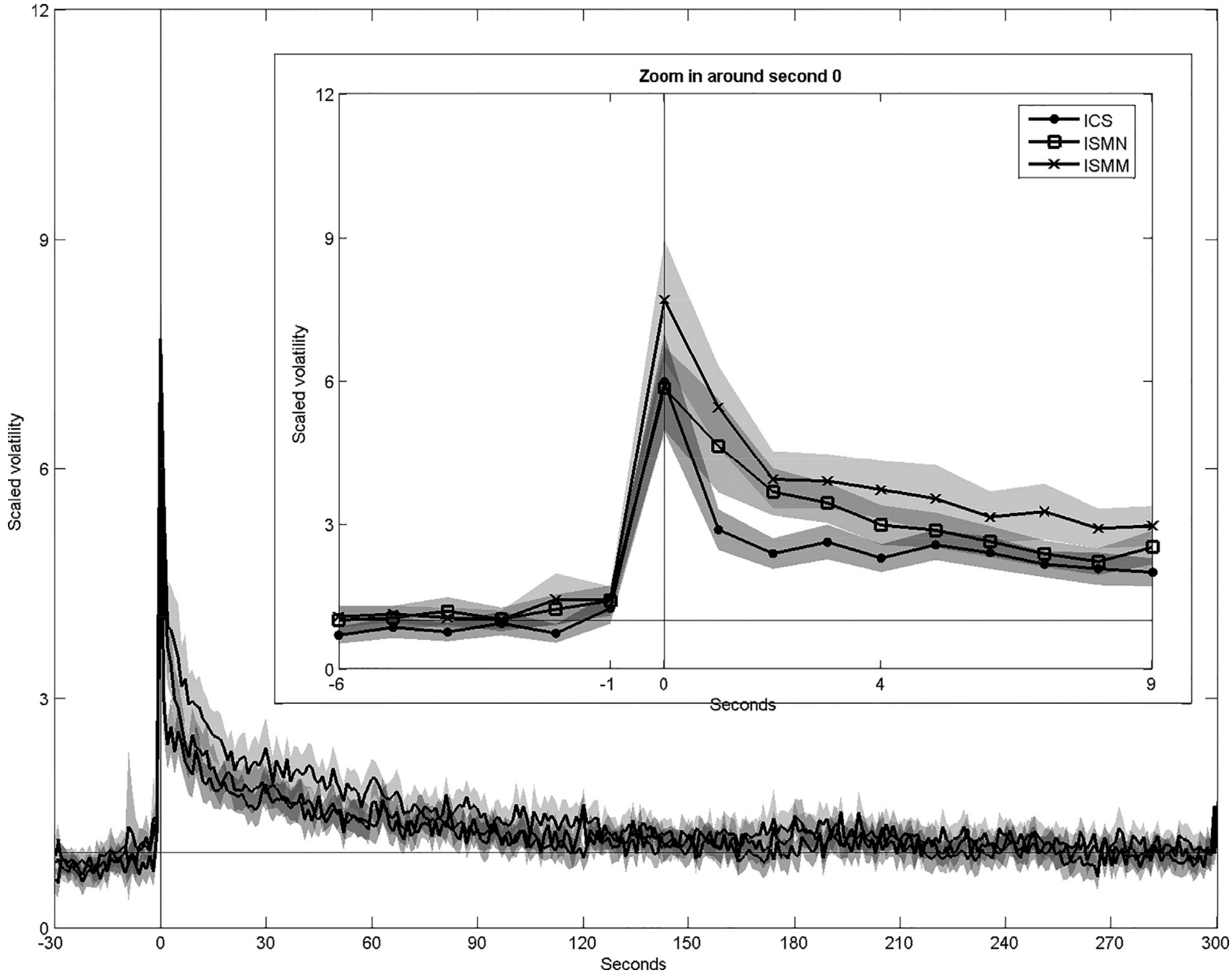


**Fig. 3.** One-second scaled return volatility of E-mini S&P 500 futures surrounding the news announcements of ICS, ISMN, and ISMM, respectively, during the early peek period from January 2009 to June 2013. ICS is the preliminary release of the Index of Consumer Sentiment, ISMN is the ISM Non-Manufacturing index, and ISMM is the ISM Manufacturing index. The release time of each index is labeled by 0 second on the *x*-axis. The scaled return volatility is calculated as the ratio between the volatility surrounding the news release and the volatility ten minutes after the news release. The shaded areas are the 95% confidence intervals for the scaled volatility measures.

during the early peek period. By contrast, although the initial one-second response of ISMM is slightly larger than that of ISMN, their decay rates are similar during the first few seconds after the news release. We will formally test these differences below.

### *6.2. Difference-in-difference tests*

The tests to be performed for volatility are similar in design to our tests on price impact. Instead of running a regression to estimate the price impact, we can measure the volatility directly using the transaction-level data. In this sense, the formal tests on the cross-sectional and time-series differences, as well as the difference-in-difference follow very much the standard approach.

The results are summarized in Table 5. Again, the tests are performed over three time horizons: the initial one second (0 s), the next four seconds (1 – 4 s), and the last five seconds (5 – 9 s). Throughout Table 5, the scaled volatility is always measured in the unit of one-second volatility. For example, for the time horizon of the next four seconds (1 – 4 s), we calculate the volatility using transaction-level data over the four-second interval and scale it by $\sqrt{4}$, and then we scale it by the one-second benchmark volatility.

Let’s focus first on the more comparable pair of ICS and ISMN. During the early peek period, the scaled volatility during the initial one second after the news release is 5.99 for ICS and 5.86 for ISMN. There is no statistically significant difference between the two. Over the next four seconds, however, the one-second scaled volatility reduces to 2.64 for ICS and to 3.87 for ISMN. A formal test of this cross-sectional difference in volatility is statistically significant. In other words, although the initial responses in volatility are similar for ICS and ISMN, the volatility decays faster for ICS during early peek and the difference is statistically significant. The same pattern is captured in Fig. 3, where the second-by-second volatility for ICS is plot-

**Table 5**
Difference-in-difference tests of scaled volatility surrounding news announcements.
The scaled return volatilities of E-mini S&P 500 are compared across indices and time periods. The early peek period is from January 2009 to June 2013, and the post period is from July 2013 to June 2016. The scaled return volatility is calculated as the ratio between the volatility surrounding the news release and the volatility ten minutes after the news release. We split the first ten seconds after the news release into the following three horizons: the initial one second "0s," the next four seconds "1 – 4 s," and the last five seconds "5 – 9 s." For each time horizon, we report the averages of the scaled volatilities and the standard errors in parenthesis below. The differences of the scaled volatilities across different indices and across different periods are also reported with their $t$-statistics given in square brackets below. $^{*}$, $^{**}$, and $^{***}$ denote significance at the 10%, 5%, and 1% level, respectively.

*Panel A: ICS preliminary (ICS) vs. ISM Non-Manufacturing (ISMN)*

| | 0 s | | | 1 – 4 s | | | 5 – 9 s | | |
|---|---|---|---|---|---|---|---|---|---|
| | During | Post | Diff=Post-during | During | Post | Diff=Post-during | During | Post | Diff=Post-during |
| ICS | 5.99 | 3.59 | −2.40*** | 2.64 | 2.21 | −0.43* | 2.36 | 1.61 | −0.75*** |
| | (0.52) | (0.53) | [−3.23] | (0.15) | (0.18) | [−1.85] | (0.12) | (0.11) | [−4.55] |
| ISMN | 5.86 | 3.77 | −2.09*** | 3.87 | 2.49 | −1.38*** | 2.63 | 1.79 | −0.85*** |
| | (0.44) | (0.25) | [−4.13] | (0.28) | (0.16) | [−4.27] | (0.13) | (0.12) | [−4.69] |
| Diff=ICS-ISMN | 0.13 | −0.18 | −0.31 | −1.23*** | −0.29 | 0.94** | −0.27 | −0.18 | 0.09 |
| | [0.19] | [−0.31] | [−0.35] | [−3.85] | [−1.20] | [2.37] | [−1.51] | [−1.08] | [0.38] |

*Panel B: ICS preliminary (ICS) vs. ISM Manufacturing (ISMM)*

| | 0 s | | | 1 – 4 s | | | 5 – 9 s | | |
|---|---|---|---|---|---|---|---|---|---|
| | During | Post | Diff=Post-during | During | Post | Diff=Post-during | During | Post | Diff=Post-during |
| ICS | 5.99 | 3.59 | −2.40*** | 2.64 | 2.21 | −0.43* | 2.36 | 1.61 | −0.75*** |
| | (0.52) | (0.53) | [−3.23] | (0.15) | (0.18) | [−1.85] | (0.12) | (0.11) | [−4.55] |
| ISMM | 7.69 | 5.70 | −1.99** | 4.45 | 2.69 | −1.76*** | 3.31 | 2.00 | −1.30*** |
| | (0.65) | (0.47) | [−2.49] | (0.30) | (0.15) | [−5.18] | (0.24) | (0.12) | [−4.80] |
| Diff=ICS-ISMM | −1.70** | −2.12*** | −0.41 | −1.81*** | −0.48** | 1.33*** | −0.94*** | −0.40** | 0.55* |
| | [−2.05] | [−3.00] | [−0.38] | [−5.32] | [−2.06] | [3.22] | [−3.47] | [−2.41] | [1.73] |

*Panel C: ISM Non-Manufacturing (ISMN) vs. ISM Manufacturing (ISMM)*

| | 0 s | | | 1 – 4 s | | | 5 – 9 s | | |
|---|---|---|---|---|---|---|---|---|---|
| | During | Post | Diff=Post-during | During | Post | Diff=Post-during | During | Post | Diff=Post-during |
| ISMN | 5.86 | 3.77 | −2.09*** | 3.87 | 2.49 | −1.38*** | 2.63 | 1.79 | −0.85*** |
| | (0.44) | (0.25) | [−4.13] | (0.28) | (0.16) | [−4.27] | (0.13) | (0.12) | [−4.69] |
| ISMM | 7.69 | 5.70 | −1.99** | 4.45 | 2.69 | −1.76*** | 3.31 | 2.00 | −1.30*** |
| | (0.65) | (0.47) | [−2.49] | (0.30) | (0.15) | [−5.18] | (0.24) | (0.12) | [−4.80] |
| Diff=ISMN-ISMM | −1.83** | −1.93*** | −0.10 | −0.58 | −0.20 | 0.38 | −0.67** | −0.22 | 0.46 |
| | [−2.33] | [−3.67] | [−0.11] | [−1.39] | [−0.90] | [0.82] | [−2.42] | [−1.28] | [1.40] |

ted against that of ISMN. Over the last five seconds, the scaled volatilities for both ICS and ISMN decay to about the same level, and there is no longer any difference that is statistically significant. Overall, this cross-sectional evidence is supportive of the hypothesis that the early peek arrangement improves the precision of the price discovery process and results in a faster resolution of uncertainty for ICS. More specifically, the improvement is observed over the four seconds (1 – 4 s) after the initial one-second response.

Comparing the scaled volatility along the time-series dimension, we see in Table 5 that for both ICS and ISM, the scaled volatilities are lower in the post period. This is consistent with our earlier observations that, in the post period, there is smaller market impact and less trading activity. During the initial second (0 s), the time-series reductions in scaled volatility are comparable for ICS and ISMN, and the final difference-in-difference test is insignificant for this time horizon. In other words, even though the time-series difference is significant for ICS and ISMN, respectively, the final difference-in-difference test reveals no significant difference in volatility over this time horizon. Over the next four seconds (1 – 4 s), the time-series reduction in scaled volatility is much smaller for ICS, indicating a slower decay in scaled volatility in the post period when early peek has been suspended for ICS. Indeed, the difference-in-difference test over this time horizon is significant. That is, the evidence that there is a slower resolution of uncertainty in the absence of early peek is robust with the control provided by ISMN. Finally, over the next five seconds (5 – 9 s), the time-series reductions in scaled volatility remain significant for both ICS and ISMN, but the difference-in-difference test reveals no significance. Hence, the time horizon over which we can uniquely identify an improvement in price discovery is the four-second period over 1 – 4 s.

Repeating the same analysis for the pair of ICS and ISMM reveals similar results. The difference-in-difference test is the strongest over the 1 – 4 s time horizon. There is some evidence for the 5 – 9 s time horizon, but the statistical significance of the test result is rather weak. Repeating the analysis for the pair of ISMN and ISMM reveals no difference between the two after the initial second, which is to be expected.

This pattern of fast convergence in volatility for ICS during the early peek arrangement is reminiscent of that for price discovery. But it adds an additional layer to the economic importance of our results. For market participants, the slower convergence of volatility observed for ISMN and ISMM means that they are trading in a higher volatility environment for longer periods of time. Overall, the empirical evidence documented in this section shows that the benefit of the tiered information release is reflected not only in faster information incorporation but also in faster resolution of uncertainty and lower return volatility. While one might argue that, with a slower speed, information eventually gets incorporated into prices because returns add up, the same cannot be said for volatility. The excess volatility is clearly a deadweight loss for most market participants, both in execution risk and liquidity cost sunk into the trading process.

## 7. 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 has 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. Their concentrated and coordinated trading leads to super fast price discovery. After a short window of roughly 200 milliseconds, there will be no further price drift afterward, implying the price discovery is accomplished rapidly by the high-frequency traders with early peek information. For general investors, as long as they do not trade at the first 200 milliseconds when the price discovery takes place, they are not disadvantaged by the informed high-frequency traders.

We further establish a causal relationship between the early peek arrangement and the fast price discovery by isolating the impact of the early peek along two dimensions. In cross section, we make use of the fact that there are other macroeconomic indices whose news releases do not have the early peek arrangement. In time-series, we take advantage of the fact that the early peek arrangement was abruptly suspended in July 2013, less than one month after the initial attention from media coverage. By performing the difference-in-difference tests on price impact and volatility, we find that the tiered information release arrangement actually leads to more efficient price discovery: faster price formation and lower price volatility. This raises interesting questions regarding the optimal arrangement in releasing market-moving information.

## Appendix A. Early peek trading in cash markets

In addition to the futures market on which 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, at 9:54:58; market prices move rapidly to reflect the new ICS information; and there is no further drift in prices after the early peek window.

Table A.1 reports the trading and the associated price impact in SPY. The ICS announcement days in the low, med, and high groups are ranked by the ICS surprise and contain the same ICS news days that we use in our main results. As reported in Table A.1, a big chunk of the early trading concentrates in 9:54:58. The average one-second turnover is 4.87 bps and 3.25 bps for the negative and positive news days, well above the average 1.32 bps turnover for the med group and the average 0.20 bps turnover when sampled across the ten-minute trading window from 9:50:00 to 9:59:59 on all ICS announcement days. For the next second, at 9:54:59, the negative and positive news days still attract higher trading, but the magnitudes of turnover have dropped sharply to 1.71 and 0.54 bps. The turnover for the med group, which contains ICS days with small index surprise is reduced to 0.28 bps, close to the average level of turnover.

In terms of price discovery, most of the actions take place at 9:54:58. The one-second returns of SPY for

**Table A1**
S&P 500 ETF return and turnover on ICS announcements.
The sample period is from January 2009 to June 2013. The Low, Med, and High groups contain the preliminary ICS announcement days, with the bottom 40%, the middle 20%, and the top 40% index surprise (actual minus the median of economists' forecasts surveyed by Bloomberg). Returns are the average log returns of S&P 500 ETF for the respective time interval and are reported in basis points. Turnover is the average number of S&P 500 ETF shares traded per second scaled by the total number of S&P 500 ETF shares outstanding and is reported in basis points. "L-M" and "H-M" denote the difference in turnover between the low and medium group, and the high and medium group, respectively. The $t$-statistics are reported in square brackets, and *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

| | Return | | | Turnover | | | | |
|---|---|---|---|---|---|---|---|---|
| Period | Low | Med | High | Low | Med | High | L-M | H-M |
| #Days | 22 | 11 | 21 | | | | | |
| ICS surprise | −4.74*** | −0.61*** | 2.51*** | | | | | |
| | [−10.3] | [−2.71] | [7.60] | | | | | |
| 9:45:00 - 9:54:56 | −1.11 | −8.82 | 4.26 | 0.17 | 0.22 | 0.18 | −0.04 | −0.03 |
| | [−0.17] | [−0.74] | [0.60] | | | | [−1.45] | [−0.85] |
| 9:54:57 | −1.88** | −0.06 | 0.89* | 0.50 | 0.17 | 0.42 | 0.33 | 0.25 |
| | [−2.54] | [−0.23] | [1.69] | | | | [1.10] | [0.99] |
| 9:54:58 | −7.78*** | −1.55 | 6.95*** | 4.87 | 1.32 | 3.25 | 3.55*** | 1.93** |
| | [−8.15] | [−1.21] | [6.65] | | | | [3.13] | [1.97] |
| 9:54:59 | −1.63 | −0.06 | −0.64 | 1.71 | 0.28 | 0.54 | 1.43*** | 0.26* |
| | [−1.52] | [−0.17] | [−1.06] | | | | [2.73] | [1.65] |
| 9:55:00 - 9:55:09 | −1.13 | 1.80 | −1.61 | 0.61 | 0.48 | 0.54 | 0.13 | 0.05 |
| | [−0.90] | [0.73] | [−1.12] | | | | [0.98] | [0.34] |

the negative and positive news days are −7.78 bps and 6.95 bps, close and slightly smaller compared with the return of E-mini S&P 500 futures in the futures market. Return on the both negative and positive news days does not drift at the next second 9:54:59. 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 −1.88 bps for the negative news days and 0.89 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, 0.50 bps for the negative and 0.42 bps for the positive news days. However, we want to emphasize that their economic significance is weak compared with the one-second volatility of 1.24 bps and the bid/ask spreads of 1.35 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 the public at 9:55:00.

## Appendix B. Market depth around announcements

Our previous results have shown that general (non high-speed) investors are only potentially disadvantaged if they trade in the early peek window during the price discovery process. In fact, if the early peek arrangement is fully public, general investors can rationally avoid the two-second window in trading due to potential information disadvantage. To further understand investors' trading behavior, we look at the order book of the E-mini S&P 500 futures around the ICS announcements.

We find that market depth reduces significantly before the ICS release, which suggests that most of the investors intentionally withdraw from the market before the announcement. We focus on the aggregate market depth up to five price levels (or up to four ticks from the best

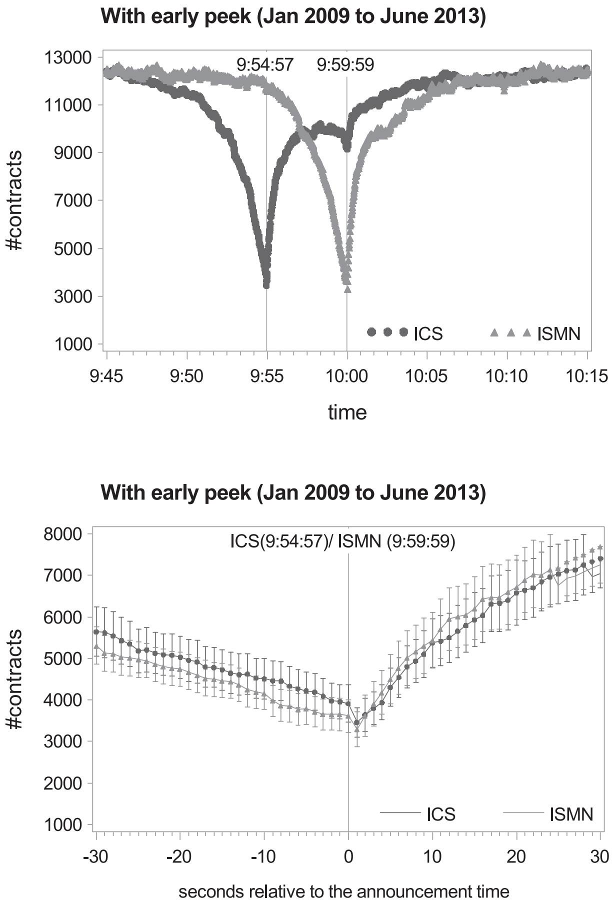


**Fig. A1.** Market depth around news announcements. The market depth is the aggregate depth, in number of E-mini S&P 500 contracts, for prices up to the five best price levels on the respective ICS and ISMN days. ICS is the preliminary release of the Index of Consumer Sentiment and ISMN is the ISM Non-Manufacturing index. The top panels plot the average market depth second-by-second from 9:45:00 to 10:15:00. The bottom panels plot the average market depth and the associated 95% confidence intervals during a 60-second window around the respective announcement time (labeled as time zero). During the early peek period, the announcement time is the end of 9:54:57 for the ICS days and the end of 9:59:59 for the ISMN days from January 2009 to June 2013. During the post peek period period, the announcement time is the end of 9:54:59 for the ICS days from July 2013 to December 2014, the end of 9:59:59 for the ICS days from January 2015 to June 2016, and the end of 9:59:59 for the ISMN days from July 2013 to June 2016.

bid and ask).[27] As shown in Fig. A.1, the market depth starts to narrow down well before the announcement time on the ICS days during the early peek period. In approximately five minutes, the average market depth drops quickly from 11,417 contracts at 9:50:00 to only 3,912 contracts at 9:54:57, indicating that most of the investors have already withdrawn from the futures market before the ICS early release and will not participate in the trading during the price discovery process, which starts from 9:54:58.

For the investors who decide to stay in the market, they are likely trading for other fundamental reasons (such as rebalancing, hedging, and liquidity provision). This can be seen from the comparison of the market depth on the ICS and ISMN releases. During a 60-second time window around their respective announcements, there is no significant difference between the market depth for the two indices.[28] This is true for both the periods with and without the early peek arrangement. The ISMN index's announcement time has always been scheduled at 10:00:00 and is well known to the community of investors. The fact that we observe similar market depth on the ICS days suggests that the investors who decide to stay in the market are likely those willing to trade despite the early peek arrangement. These investors will be involved in the trading during the price discovery process, but their motivations to trade do not hinge on whether the ICS is released with or without the early peek arrangement.

Of course, we can not rule out the possibility that some of these investors may not know that the ICS release is two seconds earlier, at 9:54:58, and could accidentally be on the side of a transaction that is trading at prices not fully reflecting the news during the price discovery process. To have an estimate for the size of such trades due to "stale" orders, we make use of the change in the market depth from the pre-announcement time at 9:54:57 to the post-announcement time at 9:54:58. Since any "stale" orders that are left on the order book will be picked up by the high-speed traders and be traded away during the price discovery process, the change in the market depth can therefore serve as an upper bound for the size of such trades against "stale" orders.

During our sample period with the early peek arrangement, the average change is 866 contracts for the aggregate market depth up to nine price levels.[29] Of these 866 contracts, the change in the market depth for the best bid and ask is 141 contracts. For the price levels beyond the best bid/ask (from one to eight ticks), the change in the market depth is 116 contracts, 155 contracts, −36 contracts, 131 contracts, 27 contracts, −83 contracts, 143 contracts, and 272 contracts, respectively. Then, assuming that the high-speed traders neutralize their positions at a two standard deviation change in the market price in their favor, the upper bound for the total profit that the high-speed traders, as a whole group, can make by picking up "stale" orders during the price discovery process is $21,208. Given that each high-speed trader needs to pay approximately $6,000 per month for the subscription of the early peek service, the profit generated by trading against "stale" orders is quite small in terms of magnitudes.[30]

[27] We also look at the market depth at price levels beyond five. The pattern remains similar. Since our message data only cover the five best price levels for the early period of 2009, we report the results based on the aggregate market depth up to the five best price levels.

[28] After the release, the market depth on both ICS and ISMN days gradually recover to their pre-announcement levels. There is a small dip in the average market depth at 9:59:59 on the ICS days during the sample period with the early peek arrangement. This is caused by other announcements that are released at 10:00:00, and is not related to the ICS index.

[29] We do not consider market depth at and beyond nine ticks from the best bid and ask, because a change of nine ticks is larger than two times the standard deviation of price movement at 9:54:58 (1.08). For these calculations, the sample period is from July 2009 to June 2013 because the market depth data we obtained from CME do not cover the first half year of 2009 for market depth above five ticks.

[30] For all our discussions, we only consider "stale" limit orders. For general investors who happen to submit market orders during the first 200 milliseconds of 9:54:58, their trades will be transacted at the intermediate prices during the price discovery process. Therefore, investors who submit market orders should also avoid the early peek window and trade only after the market price has been fully adjusted.

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