Can information be locked-up? Informed trading ahead of macro-news announcements[*]

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Abstract − U.S. government agencies routinely allow pre-release access to macroeconomic data to accredited news agencies under embargo agreements (i.e., news embargo or lockup). We use high frequency data to investigate whether there is informed trading in major equity index futures and exchange traded funds during lockup periods prior to salient macro-news announcements. Consistent with information leakage, we find robust evidence of informed trading during lockup periods ahead of the Federal Open Market Committee (FOMC) monetary policy announcements. In particular, during FOMC's lockups, both the E-mini S&P 500 futures' average abnormal order imbalance, 8.4%-9.5%, and its average abnormal price run-up, 20.5 basis points, are statistically significant and in the direction of the subsequent policy surprise. Across the four markets that we examine, estimates of informed traders' aggregate dollar profits during lockups ahead of all FOMC's surprise announcements range between $14 and $256 million. While our evidence challenges the effectiveness of the FOMC's lockup practices, we find no evidence of informed trading ahead of nonfarm payroll, CPI, and GDP data releases by other government agencies.

1 Introduction

The question of how information is impounded in capital market prices is a fundamental, long-standing one in finance. Several studies show that announcements of macro-news have economy-wide implications and affect asset prices across a wide array of markets.[1] Attesting to the importance of an orderly and accurate disclosure of macro-news, U.S. government agencies typically grant accredited news agencies with pre-release access to the information under *embargo agreements*. The news media receive the data prior to their public release (typically in *press lockup facilities*) to allow time for clarifying questions and preparing reports, but cannot disclose the information until the scheduled release. Recent media and government investigations raise serious questions about lockup practices, highlighting the potential for information leakage during embargoes.[2]

Given the widespread use of news embargoes by U.S. government agencies and the impact of macro-news on market prices, understanding the capital market consequences of lockup practices is important to ensure market integrity. On the one hand, these practices can facilitate the timely, wide, and accurate dissemination of macroeconomic information, in turn improving the informational efficiency of financial markets. On the other hand, news embargoes pose the risk of granting some market participants an unfair, if not illegal advantage, akin to corporate insiders that trade on non-public information.

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[1]The evidence shows that the release of macro-news affects prices in equity markets (e.g., Pearce and Roley (1985), French and Roll (1986), Ederington and Lee (1993), Veronesi (1999), Flannery and Protopapadakis (2001), Bernanke and Kuttner (2005), Vega (2006), Andersen et al. (2007), Tetlock (2010)), bond markets (e.g., Pearce and Roley (1985), French and Roll (1986), Ederington and Lee (1993), Veronesi (1999), Flannery and Protopapadakis (2001), Vega (2006), Tetlock (2010)), and foreign exchange markets (e.g., Urich and Wachtel (1984), Fleming and Remolona (1999), Balduzzi et al. (2001), Pasquariello and Vega (2007)). Recent work by Savor and Wilson (2013, 2014) and Lucca and Moench (2014) documents systematic unconditional return patterns in equity markets during the days around macro-news announcements.

[2]These concerns led to the tightening of lockup security requirements and recently prompted the Inspector General of the U.S. Department of Labor to recommend discontinuing the use of press lockups. Among others, see also *The Wall Street Journal* reports "A Probe on Data Releases Is Revived" in April 2013; "FBI Finds Black Boxes That Control Government Data Are Vulnerable" and "Deutsche Borse's News Service for Traders Draws Scrutiny of Investigators" in August 2013; "Labor Department Panel Calls for Ending Lockup for Jobs Data" in January 2014; and *CNBC* report "News organizations respond to Fed lockup questions" in September 2013.

In this paper, we examine for the first time the potential consequences that macro-news embargoes can have on capital market participants and the resulting price formation process due to information leakage. In particular, we use high frequency data to investigate whether there is informed trading during lockup periods ahead of macro-news releases previously shown to have the largest impact on market prices. These include the announcement of the Federal funds target rate by the Federal Open Market Committee (FOMC), as well as the release of data on nonfarm payroll and consumer price index or (CPI) by the Department of Labor (DOL), and on the gross domestic product or GDP growth by the Bureau of Economic Analysis (BEA).[3]

Consistent with the notion that news embargo practices may yield an informational advantage for some traders, we find robust evidence of informed trading activities in major equity index futures and exchange traded funds (ETFs) during lockup periods ahead of monetary policy announcements by FOMC. In particular, we document the presence of significant abnormal price run-ups and order imbalances that are in the direction of the subsequent policy surprises. The economic magnitude of our results is significant. Back-of-the-envelope calculations indicate that the aggregate dollar profits of lockup-related informed trades ahead of FOMC's surprise announcements range between \$14 and \$256 million across the four markets that we examine. Notably, we find no evidence of informed trading prior to the start of FOMC's lockup periods, consistent with a systematic link between informed trading activities and the FOMC's embargo practices. Moreover, we find no evidence of informed trading ahead of surprise announcements by other government agencies, even though their post-release informational value is comparable to the FOMC's announcements. At face value, this evidence suggests that lockup practices associated with the release of value-relevant information can in fact be effective depending on the institutional setting.

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[3]The FOMC releases the Federal funds target rate during trading hours, predominantly at 2:15 p.m., but occasionally at 12:30 p.m. or 2:00 p.m. The other announcements we examine are instead made before U.S. markets open, at 8:30 a.m. In all cases, the lockup period starts 30 minutes before the official release time.

To best capitalize on pre-release access to macro-news, an investor would want to trade an instrument that has high systematic, but low idiosyncratic, risk exposure. Moreover, the instrument should be available for trading prior to the official macro-news release time and have sufficient liquidity to minimize trading costs and price impact. The E-mini S&P 500 futures (ES) meets these criteria across all the announcements that we study. Hence, we use it as our main testing security. In supplemental tests, we also examine the E-mini Nasdaq 100 futures, the SPDR S&P 500 ETF, and the PowerShares QQQ ETF tracking the Nasdaq 100 index.[4]

In a semi-strong efficient market (Fama (1970)), an investor can profit on pre-disclosure access to information, if his private signal implies a valuation different from market expectations. The greater this difference, the more likely it is that the investor would trade and profit. Therefore, it is critical for our purposes to measure market expectations prior to macro-news releases to asses the information content of those announcements. For the Federal funds target rate, we measure market expectations prior to FOMC announcements using the implied interest rate from Federal funds futures traded at the Chicago Mercantile Exchange (CME) (e.g., Kuttner (2001), Bernanke and Kuttner (2005)). For nonfarm payroll, CPI, and GDP announcements, there are no traded instruments from which to infer market expectations. Thus, we rely instead on economists' forecasts from the Blue Chip Economic Indicators Survey to classify an announcement as a surprise.

To conduct our tests, we use two common proxies for the presence of informed trading. First, since informed trading should facilitate impounding of information and contribute to price discovery, we examine the returns of the testing security prior to the macro-news' official releases. Second, we study the corresponding order imbalances, defined as the difference between buyer- and seller-initiated trading volumes divided by total trading volume. We measure volume either by number of trades or by dollar amount

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[4]We only use these securities in our supplemental tests because the E-mini Nasdaq 100 futures is significantly less liquid than the ES and the ETFs are only available during stock market trading hours - i.e., prior to FOMC announcements.

traded, yielding two metrics of order imbalance. To measure *abnormal* returns and trading activities on announcement days, we use as a benchmark all non-announcement days in the prior 21 trading days. Then, for each type of macro-news release, we compare abnormal returns and order imbalances around surprise and non-surprise announcements. Our empirical strategy ultimately exploits the systematic variation across announcement vs. non-announcement days as well as across surprise vs. non-surprise announcements.

Our tests yield several important results. First, across all securities that we examine, we find evidence of informed trading prior to FOMC's surprise announcements and this activity is exclusively concentrated in the last thirty minutes before the official release - i.e., lockup period. In the case of E-mini S&P 500 futures, for instance, the abnormal price run-up during lockup periods prior to FOMC's surprise announcements is 20.5 basis points (t-statistic = 3.74) higher than non-surprise ones. Furthermore, the corresponding abnormal order imbalances are 8.4%-9.5% higher for FOMC's surprise announcements compared to non-surprise ones. Similar patterns emerge when we examine the E-mini Nasdaq 100 futures, the SPDR S&P 500 ETF, or the PowerShares QQQ Nasdaq 100 ETF. In contrast, we find no evidence of informed trading in the thirty minutes prior to the start of FOMC lockups, nor do we find differences in trading and returns during FOMC lockups ahead of non-surprise announcements versus non-announcement days.

In contrast to FOMC's announcements, we find no evidence of informed trading ahead of DOL or BEA announcements. This is particularly relevant, given that government investigations focused on the permeability of the DOL's lockup facilities since at least 2011. At that point, Need to Know News (NTKN), a news media organization founded in 2004 and with press credentials since 2006, was alleged of leaking information and ultimately banned from DOL's lockups.[5] In supplemental tests we examine whether our results vary around 2006, but find that our inferences are robust across subperiods.

In light of our baseline results, in the final part of the analysis, we focus on FOMC's

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[5]See "Deutsche Borse's News Service for Traders Draws Scrutiny of Investigators", *The Wall Street Journal*, August 12, 2013, by Brody Mullins and Scott Patterson.

announcements. First, we show that our inferences are robust to using more conservative definitions of surprise announcements or using the actual magnitude of the unexpected policy announcement to characterize the surprise. Second, we zoom in on the lockup window and find that, in the E-mini S&P 500 futures market, the informed order imbalances are mostly concentrated in the [-20, -10] window, followed by an abnormal price run-up in the [-10, 0] window.[6] By contrast, in the other markets we examine, both abnormal order imbalance and price run-up appear only in the last ten minutes. This evidence is consistent with the fact that the E-mini S&P 500 futures market is substantially more liquid than the other markets.

Lastly, we repeat our baseline tests while conditioning on the direction of the policy surprise and find evidence of asymmetric effects. Specifically, lockup-related informed trading occurs mainly before good news - i.e., unexpectedly large cuts in the Federal funds target rate. Short-sale constraints in the stock market may account for this asymmetry, if liquidity providers in the futures market retreat from large selling pressures when they are unable to hedge their positions using the underlying stock market. As a result, for unexpected rate hikes, short-sale constraints would limit informed investors' trading opportunities in the stock market, directly, and in the futures market, indirectly. It is also possible that informed traders use limit orders more heavily ahead of bad news surprises, rather than market orders (Baruch, Panayides, and Venkataraman (2014)). In turn, this would prevent us from correctly identifying the direction of informed trades based on conventional empirical methods.

Our analysis informs the ongoing policy debate surrounding lockup practices by testing whether macro-news lockups are associated with informed trading, consistent with information leakage. Our results raise serious questions about the appropriateness of FOMC policy announcements' embargoes, either because information may directly leak from the news media with pre-release access or from other FOMC insiders with incentives

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[6]We define "0" as the official release time.

to mimic such behavior. In contrast, despite the focus of government investigations and news media on potential information leakages from lockups of other government agencies such as the DOL, we find no evidence that supports those concerns.

Our study makes a unique contribution to the literature on the capital market consequences of macro-news announcements (see footnote 1). Existing studies show that the release of macroeconomic news has a large impact on *post-announcement* market prices. We add to this literature by showing that equity index futures' and ETFs' prices partly reflect the effect of FOMC's policy surprises during *pre-announcement* embargoes.

Our analysis is also related to more recent studies of scheduled macroeconomic announcements (e.g., Savor and Wilson (2013, 2014); Lucca and Moench (2014)). In particular, Lucca and Moench examine the behavior of equity market prices ahead of FOMC's scheduled releases. They document an *unconditional* run-up of 49 basis points in the S&P 500 index during the *24 hours* leading to FOMC's announcements and conclude that this pattern *is not* driven by *informed* trading. Different from their study, we examine the pre-release effect of FOMC's policy announcements *conditional* on their information content and focus on the relatively short lockup period - i.e., *30 minutes*, when information leakage is most likely. Our evidence indicates that there *is* in fact systematic *informed* trading ahead of FOMC's scheduled announcements.

More broadly, our study is related to the literature regarding the effects of short-lived private information on trading activity and price formation (e.g., Hirshleifer, Subrahmanyam, and Titman (1994) and Brunnermeier (2005)). Consistent with the premise of these theories, the available evidence suggests that some investors do in fact enjoy a short-lived informational advantage in a variety of contexts. For example, some investors appear to enjoy early access to information on analysts' recommendations as result of "tipping" (e.g., Irvine, Lipson, and Puckett, (2007); Goldstein, Irvine, Kandel, and Wiener (2009); Christophe, Ferri, and Hsieh (2010); Busse, Green, and Jegadeesh (2012); Kadan, Michaely, and Moulton (2014)). Other (high-speed) traders enjoy an ad-

vantage resulting from access to faster news feeds (e.g., von Beschwitz, Keim, and Massa (2013); Hu, Pan, and Wang (2013)). We find that some investors systematically enjoy a short-lived information advantage during news embargoes ahead of salient information events such as FOMC's announcements, consistent with information leakage.

The remainder of the paper is organized as follows. Section 2 provides the institutional background and develops our testable hypotheses. Section 3 describes the data and variable construction. Section 4 presents the results of our empirical analysis and Section 5 concludes.

2   Institutional background and testable hypotheses

Fama's (1970) formulation of the "strong-form" efficient market hypothesis posits that prices always completely and instantaneously reflect information about economic fundamentals. Legal constraints exist, however, that limit investors' ability to obtain and/or capitalize on private information (e.g., insider trading laws). Therefore, it is typically the public announcement of information that facilitates "semi-strong" efficient prices.

Across the many types of information events, the release of information about macroeconomic fundamentals is among those with the largest and widest potential impact on capital markets. Indeed, several studies examine the effects of macro-news announcements on prices in a variety of financial markets. These studies consistently find that macro-news releases have large and significant effects on capital market prices: in equity markets (e.g., Pearce and Roley (1985), French and Roll (1986), Ederington and Lee (1993), Veronesi (1999), Flannery and Protopapadakis (2001), Bernanke and Kuttner (2005), Vega (2006), Andersen et al. (2007), Tetlock (2010)); in bond markets (e.g., Pearce and Roley (1985), French and Roll (1986), Ederington and Lee (1993), Veronesi (1999), Flannery and Protopapadakis (2001), Vega (2006), Tetlock (2010)); and in foreign exchange markets (e.g., Urich and Wachtel (1984), Fleming and Remolona (1999),

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Balduzzi et al. (2001), Pasquariello and Vega (2007)).

Attesting to the importance of macro-news, government agencies manage tightly the disclosure process related to this information. As a matter of policy, these agencies have an interest in the timely, wide, and accurate dissemination of macro-data that would enhance the public's understanding of the information released. To foster this policy goal, it is standard practice to grant accredited news media with pre-release access to macroeconomic data, allowing time for questions and preparation of accurate reports ahead of the official releases. Counter-balancing these benefits is the recognition that pre-release access poses the risk of granting some market participants an unfair (if not illegal) advantage, if they can exploit early access to trade. Therefore, to ensure a level playing field, government agencies have protocols that impose news embargoes (or lockups), whereby the parties that are granted early access to the data would refrain from disseminating the information ahead of the scheduled releases.[7]

Macro-news embargoes, and more generally the security of government facilities where the data is stored, have recently come under increased scrutiny after vulnerabilities were found in the U.S. government system for storing and distributing macro-data.[8] This investigation came on the heels of similar internal investigations conducted earlier by the DOL, which found several violations of the news embargo protocols. Following these investigations, the DOL put in place a new set of procedures aiming to correct the most blatant violations and revoked access to its lockup facilities for some news agencies suspected of embargoes' violations (e.g., Need to Know News).

The recent investigations and the consequent tightening of the security protocols adopted in government agencies' lockup facilities suggest that information leakages are

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[7]See, for example, "April 10, 2012 Policy Statement and News Organization Agreement", "Press Lock-Up Summary", "Testimony of Carl Fillichio, Senior Advisor for Communications and Public Affairs before the Committee on Oversight and Government Reform, United States House of Representatives, June 6, 2012" available on the DOL's website at *http://www.dol.gov/dol/media/lockupnotice.htm.*

[8]See, for example, "CleanSweep Red Team Report" and "CleanSweep Mitigation Measures Acceptance Testing " available on the DOL's website at *http://www.dol.gov/dol/media/lockupnotice.htm.*

possible during lockup periods. We aim to assess this concern by examining whether and how macro-news lockups are related to pre- and post-announcement trading activities, as measured by order flows, and the associated price formation process. In particular, traders with pre-release access to information would want to trade to capitalize on it. Therefore, prior to the scheduled macro-news releases, the order flow and price movement of securities predominantly exposed to macro factors should reveal the likely presence of informed trading activities. Given the above discussion, we posit the following hypothesis:

If there is information leakage during lockups prior to macro-news announcements, then securities predominantly exposed to macro factors should experience abnormal order imbalances and market price run-ups in the same direction of the unexpected component of the subsequent macro-news release.

3 Data and variable construction

In this section, we describe the data sources, sample selection, and variable construction.

3.1 Testing securities

We use the E-mini S&P 500 futures (ES) as our main testing security for several reasons. First, the asset underlying ES contracts is the S&P 500 index. Because the underlying asset is a diversified portfolio of large stocks, traders with positions in ES contracts are exposed mostly, if not exclusively, to market-wide risk. Investors with advanced information about economy-wide news would have strong incentives to trade such products to minimize their exposure to idiosyncratic risk. Second, the ES is available for trading almost 24 hours on the Globex electronic platform of the CME.[9] This allows us to examine the trading activities associated with macro-news releases by DOL and BEA, which take

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[9]Trading on the CME Globex electronic platform for the E-mini contracts halts between 5:15 p.m.-6:00 p.m. EST every day and between 4:15 p.m. - 4:30 p.m. EST every day except for Sunday.

place at 8:30 a.m. EST before the U.S. stock market opens. Third, informed traders have strong incentives to trade in deep and liquid markets, so as to minimize their trading costs and price impact. Compared to other index products such as the S&P 500 futures and the SPDR S&P 500 ETF (SPY), the ES is substantially more liquid. According to the CME, the ES market has an average daily volume of over 2.1 million contracts and notional value of $170 billion in the second quarter of 2013.[10] Moreover, compared to securities such as stocks and ETFs, the ES allows traders to take on higher leverage and pay lower commissions. The initial and maintenance margins of the ES required by the CME are 7.7% and 7% respectively as of Aril 2014.[11] Therefore, we expect that informed trading prior to macro-news announcements, if any, would be more predominant in the ES compared to other instruments.[12]

In addition to the ES, we also examine the E-mini Nasdaq 100 futures (NQ), another liquid index futures product. Furthermore, since FOMC's releases take place during trading hours, for these announcements we also examine the two most liquid equity index ETFs: the SPDR S&P 500 ETF (SPY) and the PowerShares QQQ ETF (QQQ, tracking Nasdaq 100 index).[13]

The CME introduced the ES contracts on September 9, 1997. In our tests, we use the full history of the ES' time-stamped (to the second) transaction-level data up to June 30, 2013. The NQ contracts started trading on June 21, 1999, and again we obtain the full history of transaction-level data up to June 30, 2013. In our tests, we focus on the front-end contracts, because they are typically the most liquid contracts. We obtain

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[10]See CME Group Leading Products: Q2 2013 publication, available at *http://www.cmegroup.com /education /files/cme-group-leading-products-2013-q2.pdf.*

[11]See CME website at *http : //www.cmegroup.com/trading/equity − index/us − index/e − mini − sandp500_performance_bonds.html.*

[12]Although we predict that absolute activity of informed traders would be higher in the ES, it is not obvious that their relative activity in the same market also would be higher in the presence of liquidity-based trading. In fact, informed traders may have more opportunities to hide behind liquidity orders, making it harder for econometricians to detect abnormal activities.

[13]It is possible that informed traders are also active in over-the-counter (OTC) markets. However, given the lack of data for these markets, we have to limit our analysis to exchange-traded products.

transaction-level data on the ETFs (SPY and QQQ) from the NYSE Trade and Quote (TAQ) database. SPY's transaction-level data are available for the entire sample period, whereas QQQ began trading only on March 10, 1999. Like the futures data, our ETF TAQ data also end on June 30, 2013.

3.2   Macroeconomic announcement surprise

In this paper, we investigate the scheduled announcements by three agencies that adopt lockup practices ahead of those releases: the Federal Open Market Committee (FOMC), the Department of Labor (DOL), and the Bureau of Economic Analysis (BEA). We focus on the announcements of four types of macro-news: the Federal funds target rate (FOMC), the nonfarm payroll (DOL), the CPI (DOL), and the GDP (BEA). For each announcement type in the period between September 9, 1997 and June 30, 2013, we collect the announcement date and time, as well as the actual announcement. Table 1 provides further institutional details about these announcements.

[Table 1 about here]

To gauge the information content of macro-news announcements, it is critical to measure market expectations prior to the scheduled releases. The difference between market expectations and announced values represents the news that market prices should impound upon announcement. We adopt two different approaches to infer market expectations, depending on the macro-news type. For the Federal funds rate announcements by the FOMC, we rely on the Federal funds futures traded at the CME (see Kuttner(2001); Bernanke and Kuttner (2005)). Each trading day, there are multiple Federal funds futures contracts with different maturity dates. We first calculate the implied spot rate for the rest of the life of each contract at the end of each trading day. Then, to estimate the expected Federal funds target rate, we use the mean implied spot rate across all available contracts, weighting each contract by its daily trading volume. The difference between

the expected Federal funds rate on the day before the FOMC announcement and the announced target rate is our measure of the surprise. There are 127 FOMC announcements in our sample.[14]

For the macro-news announcements by the DOL and BEA, there are no traded instruments from which we can directly infer market expectations. Thus, we rely instead on the distribution of economists forecasts in the Blue Chip Economic Indicators Survey to infer market expectations (i.e., median economist forecast) and announcement surprises. During our sample period, there are 189 scheduled releases for each macro-news announcement by the DOL and BEA.

For each announcement type, Table 2 provides summary statistics of the expected and actual values, their difference, and the absolute value of the difference.[15] Panel A shows that the average futures-implied Federal funds rate is 2.767%, while the average target rate announced by the FOMC is 2.713%. The average and median difference between the two rates is arguably small, at less than 5.5 basis points (bp). The average (median) absolute difference is somewhat larger, 10.4 (8.3) bp. There is, however, substantial variation across FOMC's announcements. In the extremes, the FOMC's announcement surprise can reach 45.5 bp. Panels B, C, and D report similar statistics for nonfarm payroll, CPI, and GDP announcements. There is large variation in the announcement surprises in each panel. Comparing actual announcement and the absolute difference in each panel, we find that the 'relative' announcement surprise is much smaller for the FOMC events compared to the other events. This may be due to the fact that we use a continuously updated measure of expectations based on market prices of Federal funds futures for FOMC events, whereas we must rely on a relatively stale measure of

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[14]There were in fact 129 announcements during our sample period, but we drop two events due to insufficient information. The NYSE had a special closing at 1 p.m. on November 28, 2003, because it was the day after Thanksgiving. The futures market showed almost no trading on that day, making it impossible to examine the FOMC's release on the following Monday. We also exclude April 29, 2009, because trading on the Federal funds futures market drained after April 17.

[15]Since October 19, 2008, the announced target rate by FOMC are in the format of a range, with lower and upper bounds, as opposed to a single rate. In these cases, we use the mid-point of the range to calculate the reported statistics.

expectation based on economists' surveys for the other events.

[Table 2 about here]

The magnitude of the surprise matters to traders because it directly affects the potential value of access to private information about the corresponding announcement. Indeed, small surprises should not induce much informed trading, because the anticipated price update may be too small to offset the trader's transaction costs. Therefore, to conduct meaningful tests, we need to identify those surprises that would in fact provide a privately informed investor with a profitable trading opportunity. To this end, for each announcement type, we construct an indicator variable, SUR, that equals one when the the surprise exceeds certain thresholds and zero otherwise. For the FOMC announcements, in our baseline tests, we set the thresholds at ± 12.5 bp because the minimum adjustment in the Federal funds target rate is 25 bp. Hence, SUR_{FOMC} is equal to one whenever the FOMC announcement surprise is outside the ± 12.5 bp range.[16]

It is important to note that, since the inception of the recent financial crisis, the Federal Reserve adopted additional policy measures and the corresponding announcements soon became more salient than the traditional Federal funds target rate announcements. In November 2008, the Federal Reserve began its Quantitative Easing (QE) programs, i.e., large-scale open-market purchases of assets such as treasuries and mortgage-backed securities, to reduce borrowing rates. Together with the scheduled announcement of the Federal funds target rate, the corresponding press releases routinely provided information about the Federal Reserve's stance regarding its QE programs. Following prior studies (e.g., Gagnon et al (2011), Krishnamurthy and Vissing-Jorgensen (2011), Hamilton and Wu (2012)), we identify the information content of QE-related announcements

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[16]The FOMC adopted a new policy of setting a range for the target rate since October 19, 2008. For the corresponding 38 FOMC announcements, we use the following method to identify significant surprises: if the future implied rate is above the upper bound or below the lower bound of the announced target rate range by at least 12.5 bp, SUR_{FOMC} is equal to one, and zero otherwise. Our results are robust, if we use instead the difference between the futures-implied rate and the the target range midpoint to define surprises.

by the resulting daily change in the realized rate of the ten-year treasury on the FOMC announcement date. Specifically, we first calculate the standard deviation of the daily change in the realized rate using data from ten days before and ten days after each announcement. If the magnitude of the realized rate change on the announcement day exceeds 1.75 times the rolling-window estimate of its standard deviation, we classify it as a surprise.[17]

For the macro-news announcements by DOL and BEA, it is less obvious how to define large surprise announcements. It seems reasonable that the surprise in an announcement would be more salient to investors when the announced values fall in the tails of the economist forecasts' distribution. Thus, in this study, we set $SUR_{DOL/BEA}$ equal to one when the announced value is outside the 10th and 90th percentiles of economists' forecasts and zero otherwise. For robustness, we also experiment with alternative definitions of surprises. For instance, we use the minimum and maximum forecasts as the thresholds or standardize the announcement surprise by the rolling-window standard deviation of the same macro variable and require it to be beyond some threshold, e.g. 1.75 or 2. Our inferences do not vary across the different methods.

In our baseline tests, we do not differentiate between good and bad news surprises. However, unexpected increases in the Federal funds rate or the CPI and unexpected decreases in the nonfarm payrolls or GDP convey negative information to capital market participants. Therefore, in these instances, we reverse the signs of the order imbalances and returns so that all surprise announcements should be associated with positive abnormal order imbalances and returns in the presence of informed trading. Then, in our last set of tests, we separate good and bad news surprises to assess whether they have an asymmetric impact on trading activity and returns around macro-news announcements.

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[17]Our results do not change materially, if we use five- or three-year treasuries, or if impose more stringent requirements on the magnitude of the standardized daily change in treasury rates on the announcement date, e.g., greater than 2 standard deviations.

Table 3 shows the annual breakdown of the number of events based on the surprise announcement indicator, SUR. Out of 127 FOMC events, 25 are classified as surprise announcements. There are more surprise announcements in the first half of the sample period and 2005 is associated with the most surprises in a year, seven. For the other announcement types, there are no obvious time-series patterns in the distribution of surprises. Overall, surprise announcements account for one quarter to one third of the total sample of 189 announcements by the DOL or BEA.

[Table 3 about here]

3.3 Measurement of informed trading

Informed trading is not directly observable. We perform two sets of tests to assess the presence of informed trading. First, we examine the return of the testing security since informed trading should contribute to price discovery. Second, we study the order imbalance in the testing security defined as (B-S)/(B+S), where B (S) denotes the aggregate buyer-initiated (seller-initiated) trading volume. We construct the order imbalance using two measures of trading volume, the number of trades or the dollar trading volume, yielding two metrics of order imbalance measures, OIN (number of trades-based) or OID (dollar volume-based) respectively. Compared to the event-window returns, order imbalances are more direct measures of informed trading because their interpretation does not rely on the role of informed trading in price discovery process.

The transaction-level data from the CME do not flag the direction of the transaction nor do they contain matched quotes. Therefore, we rely on the tick rule to assign trade directions. Namely, a transaction is classified as buyer-initiated (seller-initiated), if the transaction price is above (below) the last different transaction price. We exclude out-of-sequence trades from the analysis. Because there can be multiple transactions in one second and the data are only stamped to second, we first calculate volume-weighted

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price for each second and then apply the tick rule to the bulk of transactions occurring in the same second. We also calculate futures returns using the volume-weighted prices to reduce measurement error. For the two ETF securities, we obtain the quote data in addition to the transaction data from the TAQ and adopt Lee and Ready (1991) algorithm to determine the trade direction. Namely, we compare the transaction price to the midpoint of the bid and ask quotes and, if the transaction price is above (below) the midpoint quote, it is classified as buyer-initiated (seller-initiated). In instances where the transaction price is equal to the midpoint, we instead use the tick rule to identify the direction of the trade.

In our baseline analysis, we examine three event windows: the pre-lockup period from one hour before to half an hour before a macro-news announcement, [-60,-30]; the lockup period from half hour before to the announcement, [-30,0]; and the post-lockup one-hour period following the official release, [0,60]. Table 4 reports the mean, standard deviation, and median for each measure of informed trading in each event window. To set the benchmark for each variable, we use the same trading hour windows during all non-announcement days in the 21 trading days prior to the current announcement or since the last announcement, whichever is fewer. Each panel in Table 4 shows summary statistics for the variables of interest during the control days (ANN=0), the non-surprise announcements (SUR=0), and the surprise ones (SUR=1). Overall, we observe large differences across groups, especially during the [-30,0] lockup period. In the next section, we use regression analysis to test for differences in the price run-up and order imbalance measures across the three sets of trading days.

[Table 4 about here]

4 Results

4.1 Abnormal activity before the announcement

Before examining the lockup period closely, we plot the average minute by minute cumulative returns on the E-mini S&P 500 futures from 9:30 a.m. on the day before the announcement to 4 p.m. on the announcement day, in Figure 1. To facilitate comparisons, the cumulative returns for different announcement types are plotted against the same scale in the four panels. Consistent with the findings reported by Lucca and Moench (2014), we find that there is a clear (unconditional) return run-up before FOMC announcements and this pattern arises long before the start of FOMC's lockup periods. In contrast, we find no evidence of significant price run-ups before the announcements by the DOL and BEA, consistent with Savor and Wilson (2013, 2014).

[Figure 1 about here]

Next, in Panels A-D of Figure 2, we zoom in on the two-hour window around the four types of macro-news announcements. In each panel, we plot the cumulative returns starting one hour before non-surprise announcements (SUR=0) using a dashed line and before surprise announcements (SUR=1) using a solid line. Across all event types, the evidence indicates that surprises are associated with a larger price impact compared to non-surprise announcements, consistent with surprises conveying new information to market participants. However, the timing of the returns around the official releases are notably different across event types. On the one hand, Panel A of Figure 2 shows that, during the thirty-minute preceding the FOMC lockup period, there is no difference between price run-ups associated with surprise and non-surprise announcements. However, the two return-paths begin to diverge notably during the lockup period and continue to do so following the official release time. Moreover, FOMC surprise announcements are associated with greater post-announcement return volatility. On the other hand, panels

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B-D of Figure 2 show that there is little, if any difference between cumulative returns associated with non-surprise and surprise announcements prior to the official release of nonfarm payroll, CPI, and GDP data by the DOL and BEA. Moreover, although BEA and DOL surprise announcements are associated with relatively large price jumps following the official releases, there are no notable differences in the post-announcement return volatility between non-surprise and surprise announcements after the initial jump.

[Figure 2 about here]

In Figures 3 and 4, we plot the minute-by-minute order imbalance based on number of trades (OIN) or dollar volume (OID), respectively, for the two-hour period around the four announcement types. Across the board, the order imbalance evidence in the two figures is consistent with the return patterns documented in Figure 2. Specifically, in Figures 3 and 4, Panel A shows that for FOMC events the order imbalance is small and largely random before lockups both for surprise and non-surprise announcements. During pre-release lockups, however, most minutes' order imbalances tend to be in the direction of the subsequent announcement surprise (above the zero line) and larger in magnitude. In contrast, during the same period, the order imbalances of non-surprise announcements continue to be scattered and small. After the official release, both for surprise and non-surprise announcements, the order imbalances become more balanced and smaller in magnitude - as a result of higher aggregate trading volumes that may be due to lower information asymmetry and uncertainty. Panels B-D of the same figures focus on DOL and BEA releases. Consistent with the return plots, there are no obvious patterns in the pre-release order imbalances associated with surprise or non-surprise announcements.

[Figure 3 about here]

[Figure 4 about here]

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Overall, Figures 2-4 show that there are notable differences in capital market activities across surprise and non-surprise announcements during the lockup period before FOMC announcements. To assess the statistical significance of these differences, we regress the cumulative return, OIN, and OID for each event window around the official release time (i.e., [-60,-30], [-30,0], [0,60]) on the announcement dummy and the surprise dummy. Table 5 reports the ordinary least squares (OLS) coefficient estimates from these models.

Panel A of Table 5 reports the regression results for FOMC announcements. Columns 1 to 3 focus on the pre-lockup window (i.e., [-60,-30]). The evidence shows that neither ANN nor SUR are associated with significant market activity (i.e., return and order imbalance) in the ES before FOMC lockups. To gauge the differences between surprise announcements and non-announcement days, we report the results of Wald tests in the last two rows of each column - the first row reports the sum of ANN and SUR coefficients and the second row reports the corresponding p-values. The results of these tests are not statistically significant at conventional levels, suggesting that there is no difference in market activities between surprise announcement days and non-announcement ones.

[Table 5 about here]

Columns 4 to 6 report results for the lockup period, i.e., event window [-30,0]. The ANN dummy coefficient estimates is not significant in any of the three columns, indicating that FOMC non-surprise announcements are not associated with abnormal trading activities and returns during the lockup. However, the SUR dummy coefficient estimates is significant in all models. In the cumulative return model, the coefficient is 20.51 (t-statistic=3.74). Thus, during the average lockup period prior to FOMC surprise announcements the abnormal price run-up is 20.51 bp higher compared to FOMC non-surprise announcements. The Wald test shows that, relative to non-announcement trading days, the lockup period ahead of surprise announcements is associated with a statistically significant average abnormal return of 17.20 bp (p-value<0.01). Moreover,

we find that there are significantly more market orders executed in the direction of the subsequent surprise. In particular, the SUR coefficient estimates in Columns 5 (OIN model) and 6 (OID model) are equal to 8.41 and 9.48, with t-statistics of 3.76 and 3.30, respectively. Hence, the number and dollar volume of market orders executed in the direction of the subsequent surprise exceed those in the wrong direction by 8.41% and 9.48% of the total volume, respectively. Given that the typical order imbalance is less than one percent in this liquid market, these magnitudes are economically large. Based on the estimates in Columns 4 to 6, back-of-the-envelope calculations suggest that the aggregate dollar profit of informed trades across all lockup periods prior to FOMC surprise announcements range between $13.1 and $146.4 million.

Columns 7 to 9 of Panel A focus on market activities in the one hour following the official FOMC releases. We find that the post-release abnormal returns and order imbalances associated with FOMC surprise announcements are not significantly different from those typically associated with non-surprise announcements. Overall, the evidence is consistent with information leakage during media lockup periods, whereby informed investors take advantage of the information in FOMC announcements by trading actively (at least) in the ES futures market.

Panels B, C, and D report the results of the analysis for the release of nonfarm payroll, CPI, and GDP data by the DOL and BEA. Consistent with the patterns in Figures 2-4, we find no statistically significant evidence of informed trading in the ES futures market before those announcements.

4.2   Subperiod analysis

In this subsection, we investigate whether there is a structural break in our baseline results around 2006. This is when a news agency accused of leaking information, Need to Know News, was granted access to the lockup rooms. In particular, we augment our baseline regression models by adding a dummy variable, POST, which takes a value of

one for observations in or after 2006 and zero otherwise. We also interact POST with the ANN and SUR dummies to gauge the change in the effect of surprise announcements on trading activities during lockups. Table 6 reports the OLS estimation results.

[Table 6 about here]

In summary, the coefficient estimates of the SUR indicator remain largely unchanged and the interaction terms are not statistically significant in most specifications. These results are not consistent with the notion that Need to Know News exacerbated information leakage before FOMC announcements or facilitated informed trading before the BEA or DOL announcements. The (lack of) evidence for the latter announcement types, however, should be interpreted with caution. It is possible that a systematic lack of liquidity in the index futures markets may limit the informed traders' ability to capitalize significantly on information leakages ahead of DOL and BEA announcements. To assess this possibility, Figure 5 plots the average number of trades and dollar volume in every minute of a trading day. Panels A, B, C, and D correspond to the full sample, the non-announcement, the non-surprise announcement, and the surprise announcement days, respectively. Across the four panels, it is clear that the futures trading volume is substantially lower when the stock market is closed (before 9:30 a.m. and after 4:00 p.m.). Hence, even if a trader has private information as early as 8 a.m., it may be hard to capitalize on it in the futures market without drawing the attention of regulators and other investors.[18] In contrast, the typical market liquidity is much higher during FOMC lockups, which can facilitate informed trading activities.

[Figure 5 about here]

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[18]Relatedly, it is possible that informed trading ahead of DOL and BEA official data releases would target other markets that we are not able to examine due to data limitations. For instance, given that macro-news also affect exchange rates, it may be optimal for informed investors to trade in the OTC FX market, the largest round-the-clock financial market in the world.

4.3 Robustness

Since we find evidence of informed trading only prior to the FOMC announcements, we focus on these events in our remaining tests. In this subsection, we discuss the results of several tests that aim to assess the robustness of our baseline results.

First, we repeat our regression analysis using alternative definitions of surprise announcements and report the results in Table 7. Here, the SUR indicator is set to equal to one, if the absolute value of the announcement surprise is above 17.5 bp (Panel A) or above 20 bp (Panel B). Increasing the threshold of surprise announcements reduces the number of surprise announcements to only 22 in Panel A and 18 in Panel B. Nonetheless, we continue to find that the effect of SUR on the returns and order imbalances observed during FOMC lockups is statistically significant in line with our baseline results. In Panel C, we use the absolute value of the announcement surprise (AbsDiff) instead of the surprise indicator, SUR. The results are again statistically significant and consistent with our earlier findings.

[Table 7 about here]

Second, we examine the sensitivity of our results to changing the definition of surprise announcement during the QE period - i.e., from October 2008 to June 2013. During this period, the FOMC announced target rates in the format of a range, rather than a point estimate. In Panel A of Table 8, we use the midpoint of the range, rather than its lower and upper bounds, to define surprises. For the period before October 2008, we retain the same baseline definition of surprise announcement used in Table 5. Adopting this approach increases the number of FOMC surprise announcements to 38. Although our inferences remain unchanged, the economic and statistical significance of our results decreases somewhat, suggesting that the additional surprise events add noise to our tests.

During the QE period, in addition to its target rate policy, the FOMC announcements contained arguably important information about its large-scale asset purchase programs

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(i.e., QE_1, QE_2, and QE_3). This additional information in FOMC releases may contaminate our baseline definition of surprise announcements. To address this concern, in Panel B of Table 8, we use the realized changes in the 10-Year treasury rates to define surprises after October 1, 2008, while keeping the same definition based on Federal funds target rates before that date. When we use this alternative approach to define surprise announcements for the QE period, our main inferences remain the same.

[Table 8 about here]

4.4 Other testing securities

In this subsection, we turn our attention to the abnormal trading activities that may take place in other asset markets. For the reasons explained in the previous section, we examine the E-mini Nasdaq 100 futures (NQ), the SPDR S&P 500 ETF (SPY), and the Power- Shares QQQ ETF (QQQ). Specifically, we repeat our main tests using these three additional securities and present the results in Table 9.

[Table 9 about here]

Similar to our main testing security (ES), Columns 4, 5, and 6 of Panels A, B, and C show that there are significant abnormal price run-ups and informed order imbalances in NQ, SPY, and QQQ markets, respectively, during FOMC lockups. Based on the coefficient estimates reported, back-of-envelope calculations suggest that informed trades across the four markets examined (ES, NQ, SPY, and QQQ) earn aggregate profits ranging between $13.9 and $255.7 million during the FOMC lockups ahead of surprise announcements. Overall, this evidence further supports the notion that there is informed trading during the lockup periods prior to FOMC's announcements.

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4.5 Zooming in on the lockup window

In this subsection, we divide the FOMC lockup window into three ten-minute periods (labeled [-30,-20], [-20,-10], and [-10,0]) and examine the informed trading activity in each of the four testing securities within each sub-window. Table 10 reports the results.

[Table 10 about here]

Panel A of Table 10 reports the OLS estimates for the ES security. The estimates in Columns 1, 2, and 3 show that there is no abnormal return or order imbalance in the first ten minutes of the lockup period. In contrast, the results in Columns 4, 5, and 6 indicate that there is a large and significant informed order imbalance before surprise announcements in the window [-20,-10]. The ES price run-up, however, is not significant in this sub-window. Specifically, the estimate coefficients on SUR are 7.55 and 10.59 in the OIN and OID regressions with t-statistics of 2.02 and 2.32, respectively. As shown in Column 7, the ES' price run-up materializes mainly in the last ten minutes prior to the FOMC official release, with an estimated coefficient on SUR of 17.88 bp and a t-statistic of 5.25. During the same period, the ES's informed order imbalance becomes slightly smaller in magnitude and only marginally significant. In Panel B of Table 10, we repeat our pre- and post-2006 analysis for the three ten-minute sub-windows. We find similar evidence for the pre- and post-2006 periods, except that in the last ten-minute sub-window, there are large and significant informed order imbalances in the pre-2006 period, but no significant informed order imbalance in the post-2006 period.

In Panels C, D, and E of Table 10, we use the E-mini Nasdaq 100 futures, the SPDR S&P 500 ETF, and the PowerShares QQQ ETF, respectively, to repeat the analysis reported in Panel A. We find that, across those three markets, the abnormal price run-ups and informed order imbalances are concentrated in the last ten minutes prior to the FOMC official release.

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Overall, the evidence suggests that it takes some time during the lockup period for informed traders to capitalize on the FOMC announcement surprises. Moreover, consistent with the notion that liquidity affects privately informed investors' trading venue selection, it appears that the to-be announced surprise first affects the most liquid E-mini S&P 500 futures market and then spills over to other less liquid markets.

4.6 Asymmetric impact of information leakage?

A natural question is whether good and bad news associated with FOMC announcements have the same effect. To investigate whether there is asymmetric impact of the announcement surprise, we break the SUR dummy into two dummies: Bad, which equals one when the announced Federal funds target rate is above the expectation by at least 12.5 bp and zero otherwise, and Good, which equals one when the announced Federal funds target rate is below the expectation by at least 12.5 bp and zero otherwise. Of the 25 surprise announcements, six are bad news surprises (Bad = 1) and 19 are good news surprises (Good = 1). We replace the SUR dummy with these two indicators in our regressions. Table 11 reports the OLS regression results for each of our four testing securities: the E-mini S&P 500 futures (Panel A), E-mini Nasdaq 100 futures (Panel B), the SPDR S&P 500 ETF (Panel C), and the PowerShares QQQ ETF (Panel D).

[Table 11 about here]

The evidence in Table 11 reveals several patterns. First, consistent with the earlier findings, there is no abnormal price run-up or order imbalance *during the pre-lockup* period independent of the direction of the subsequent surprise. Second, it appears that *informed trading activity* is *asymmetric during lockups* ahead of FOMC surprise announcements. On the one hand, we find large and statistically significant price run-ups in the lockup periods ahead of *good news* surprises, with the magnitude ranging from

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19.06 bp in the ES to 28.24 bp in the QQQ ETF. On the other hand, for *bad news* surprises, we observe price drops ranging from -16.35 bp in the ES to -25.35 bp in the NQ. However, possibly due to the small sample size, none of the four estimates is significant at conventional confidence levels. Third, there are large and significant buyer-initiated order imbalances *during lockups* ahead of *good news* surprises. In contrast, we find no evidence of significant seller-initiated order imbalances for *bad news* surprises. Lastly, *during the post-lockup* period, prices drop significantly following bad news surprise, although order imbalances are not statistically significant.

Overall, it appears that the statistical significance of abnormal trading activities during FOMC lockups is mainly due to good news surprises. A potential reason for the asymmetry may be the existence of short-sale constraints in the stock market. Such constraints would directly cause the asymmetry in run-ups of the two ETF products, because informed traders' ability to trade on the information would be limited. The same constraints may also explain the asymmetry in the futures markets, if they affect the ability of liquidity providers in these market to hedge their positions. Another possibility is that informed traders rely on limit orders ahead of bad news surprises, rather than market orders (Baruch, Panayides, and Venkataraman (2014)). This, in turn, would prevent us from correctly identifying the direction of their trades based on conventional empirical methods (i.e., the tick-rule or the Lee and Ready (1991) algorithm).

5   Conclusion

In this study, we examine the unintended consequences that macro-news embargoes (i.e., lockups) have on capital markets. In particular, we use high frequency trading data to investigate whether there is informed trading ahead of macro-news announcements, consistent with information leakage.

We find robust evidence of informed trading, as measured by abnormal price run-up

and order imbalance of equity index futures and exchange-traded funds, during the lockup periods ahead of FOMC announcements. Based on our estimates across the four markets that we examine, the aggregate dollar profits of informed trades during all lockup periods prior to FOMC surprise announcements range between $14 and $256 million. Overall, our evidence challenges the effectiveness of the FOMC's lockup practices. In particular, our results are consistent with information leakage directly from the news media or from other insiders mimicking such behavior during the embargo.

Recent government investigations and media attention has focused on the possibility that some news agencies would violate news embargoes of government agencies such as DOL. However, we find no evidence to support those concerns for the asset markets that we can examine in conjunction with the release of nonfarm payroll, CPI, and GDP data. Notwithstanding, it is worth noting that the lack of evidence in the futures market does not prove absence information leakage prior to nonfarm payroll, CPI, and GDP announcements. Indeed, it is possible that informed trades are routed to other markets that are more liquid during after-hour trading - e.g., OTC FX market, which data limitations prevent us from analyzing. We leave further analysis of this issue to future research.

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(a) FOMC

(b) Nonfarm payroll

(c) CPI

(d) GDP
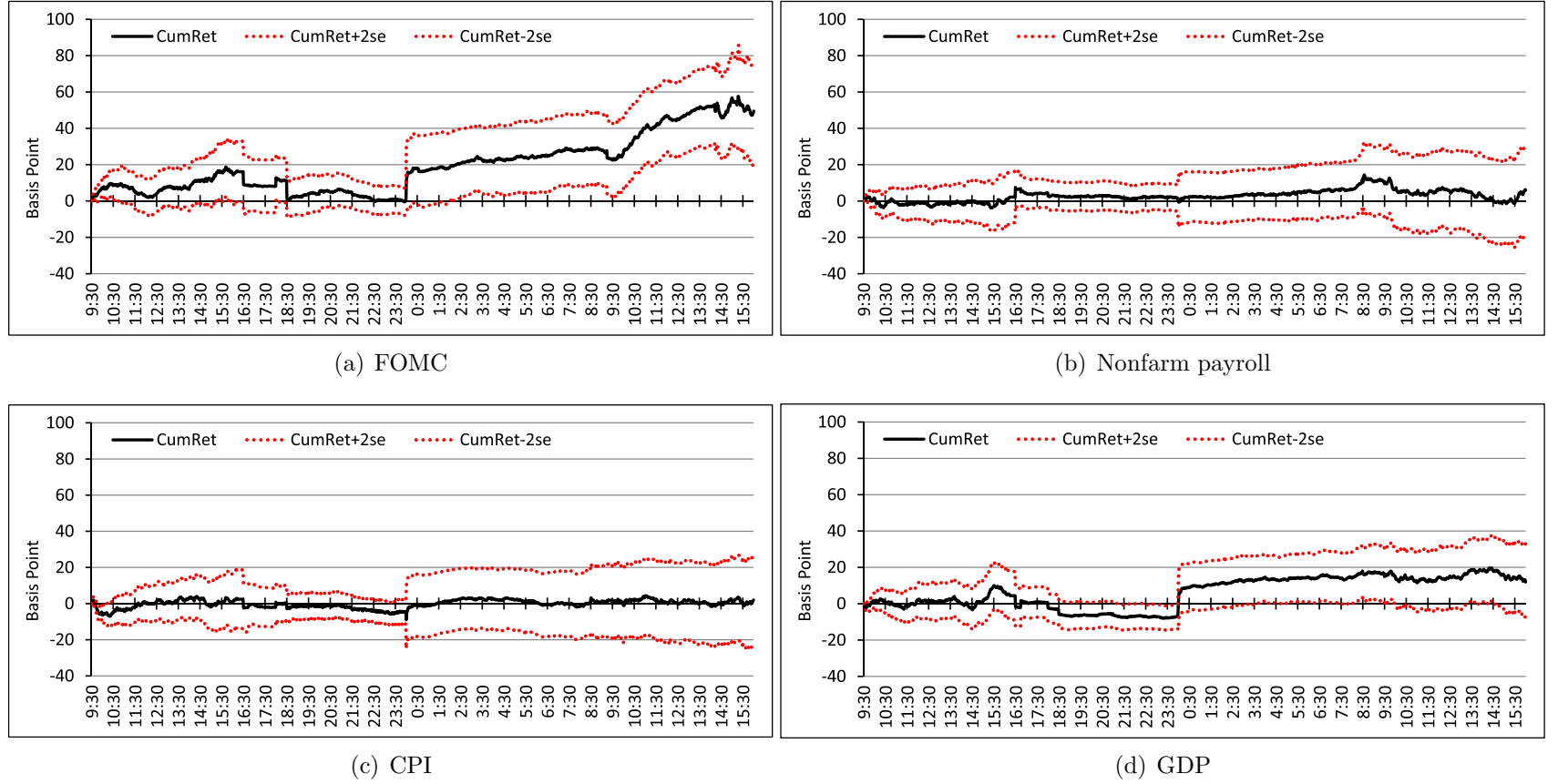
Figure 1: Cumulative returns around macroeconomic announcement days

This figure plots the minute-by-minute cumulative returns in the E-mini S&P 500 futures from 9:30 a.m. of the day before the macroeconomic announcement day to 4 p.m. of the announcement day. The black solid line is the average cumulative returns of all announcements in our sample. The red dashed lines represent the 95% confidence intervals of the average cumulative returns.
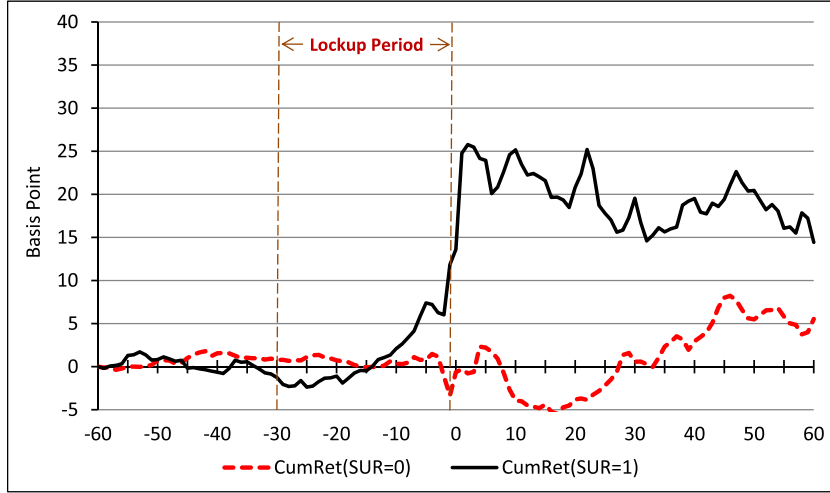
(a) FOMC
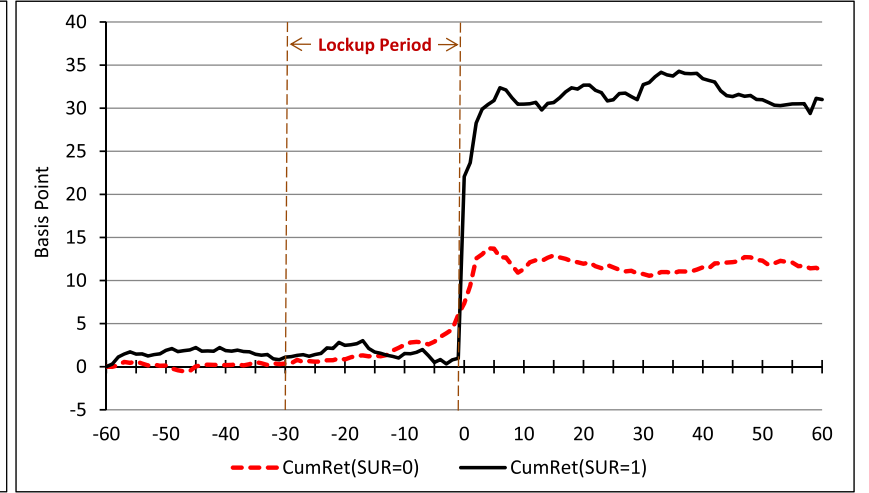
(b) Nonfarm payroll
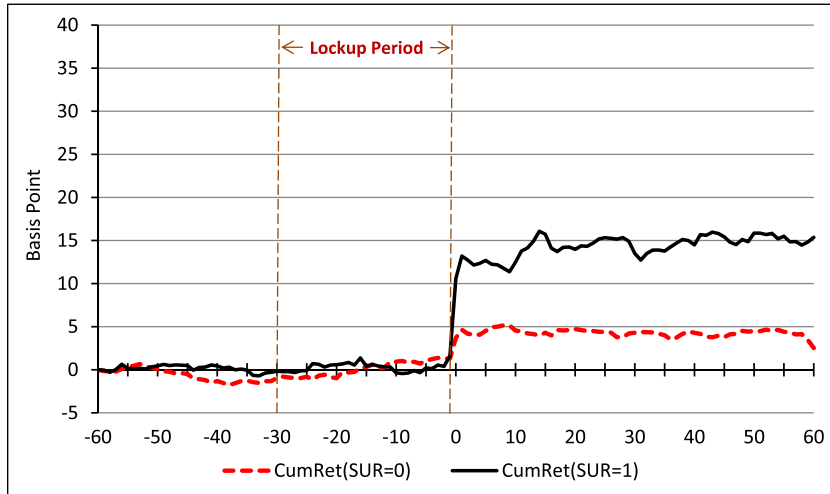
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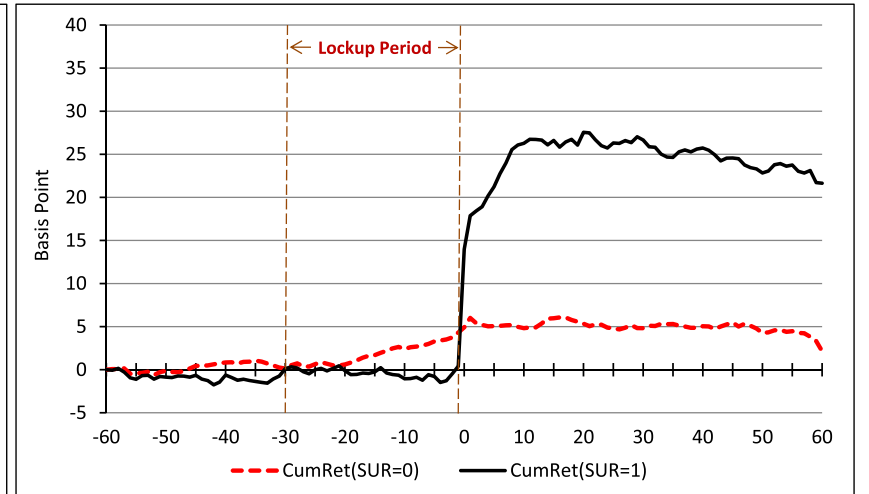
(d) GDP

Figure 2: Cumulative returns in the two hours around the announcement

This figure plots the minute-by-minute cumulative returns in the E-mini S&P 500 futures in the two hours around the macroeconomic announcement. The black solid line is the average cumulative returns of the surprise announcements (SUR=1) and the red dashed line is the average cumulative returns of the non-surprise announcements (SUR=0). "Lockup Period" corresponds to the event window [-30,0], where "0" is the official release time of the macro-news.
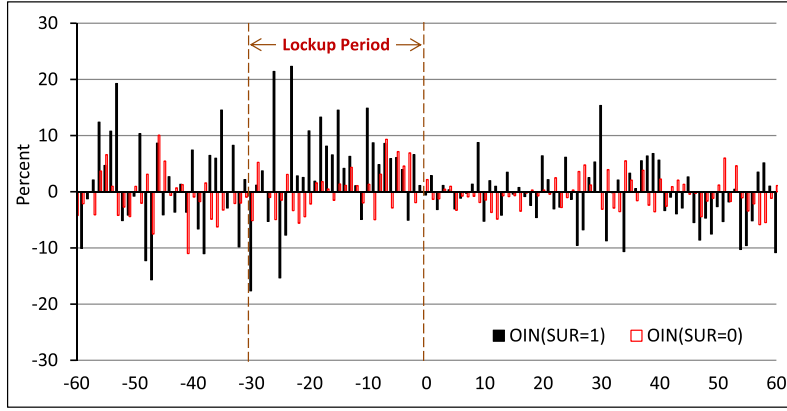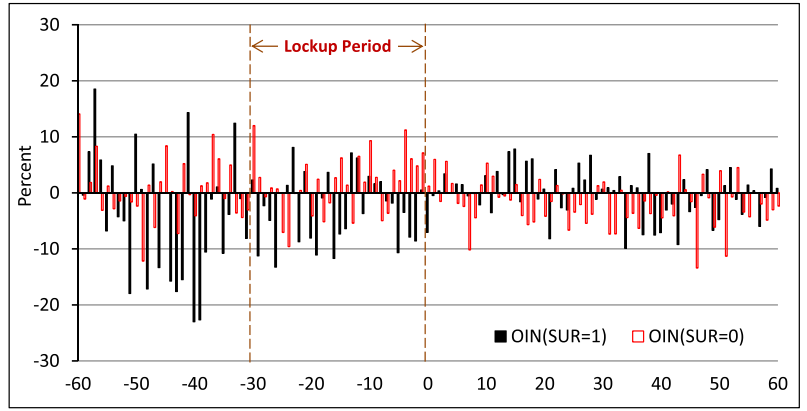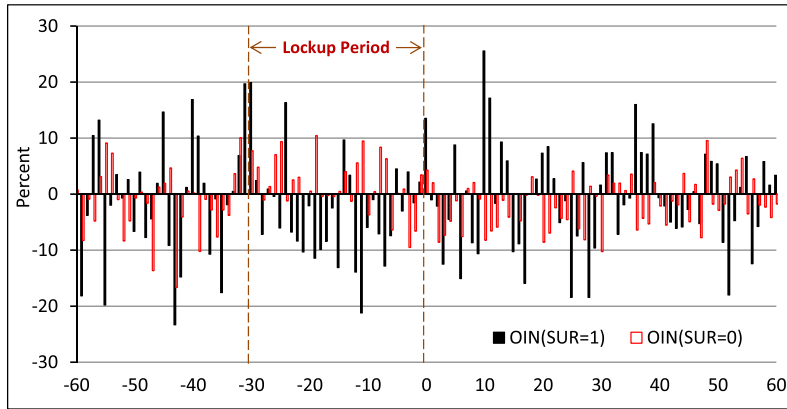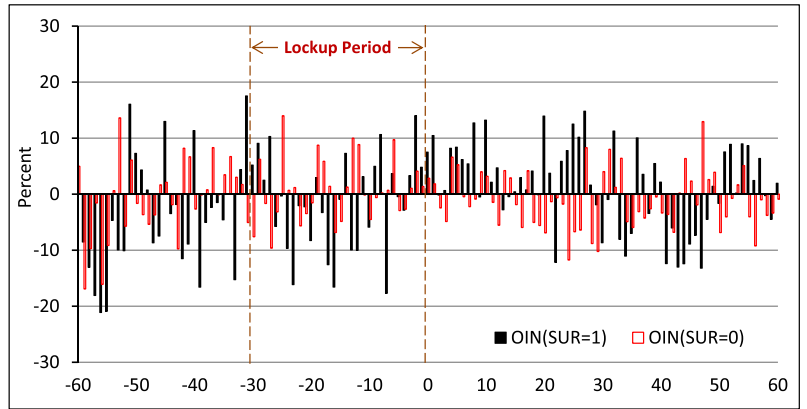
Figure 3: Order imbalance based on number of trades in the two hours around the announcement

This figure plots the minute-by-minute order imbalance based on number of trades (OIN) in the E-mini S&P 500 futures in the two hours around the macroeconomic announcement. The black bar is the average OIN of the surprise announcements (SUR=1) and the red dashed line is the average OIN of the non-surprise announcements (SUR=0). "Lockup Period" corresponds to the event window [-30,0], where "0" is the official release time of the macro-news.
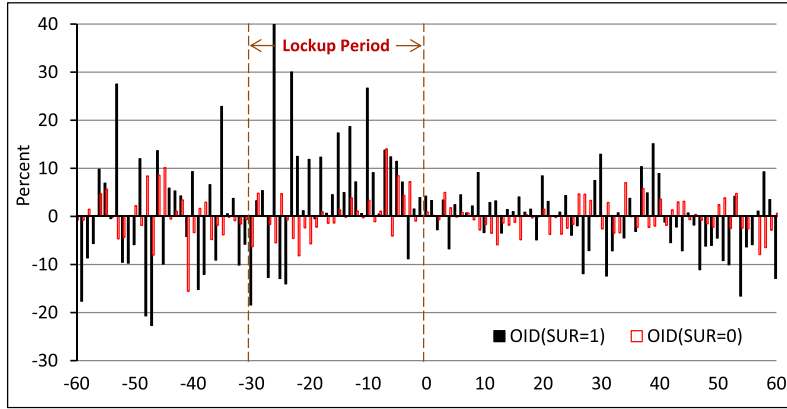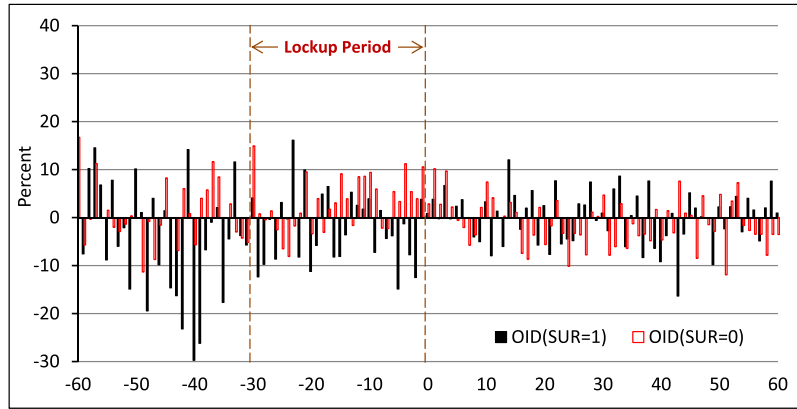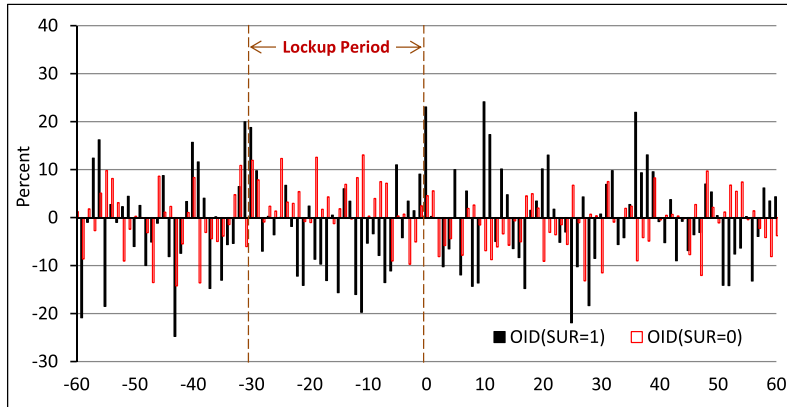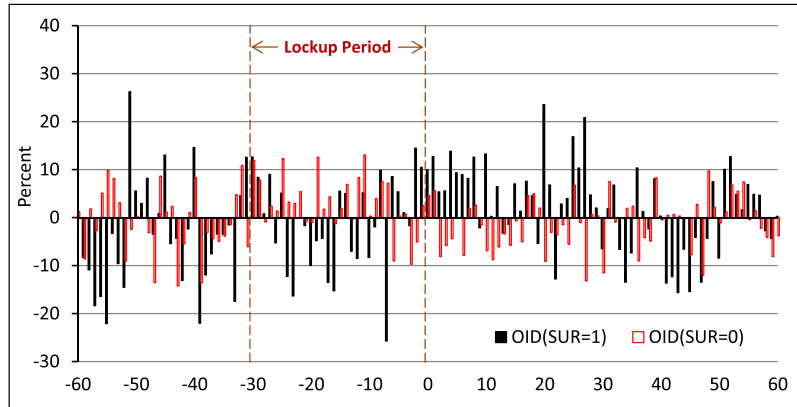
Figure 4: Order imbalance based on dollar volume in the two hours around the announcement

This figure plots the minute-by-minute order imbalance based on dollar volume (OID) in the E-mini S&P 500 futures in the two hours around the macroeconomic announcement. The black bar is the average OID of the surprise announcements (SUR=1) and the red dashed line is the average OID of the non-surprise announcements (SUR=0). "Lockup Period" corresponds to the event window [-30,0], where "0" is the official release time of the macro-news.
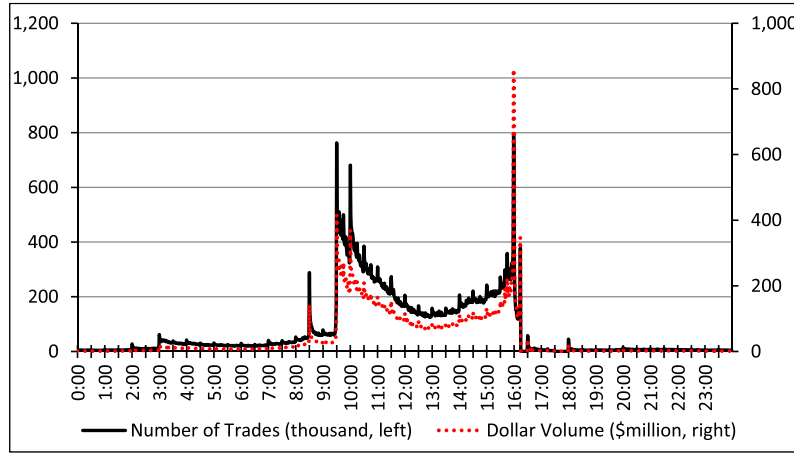
(a) Full sample
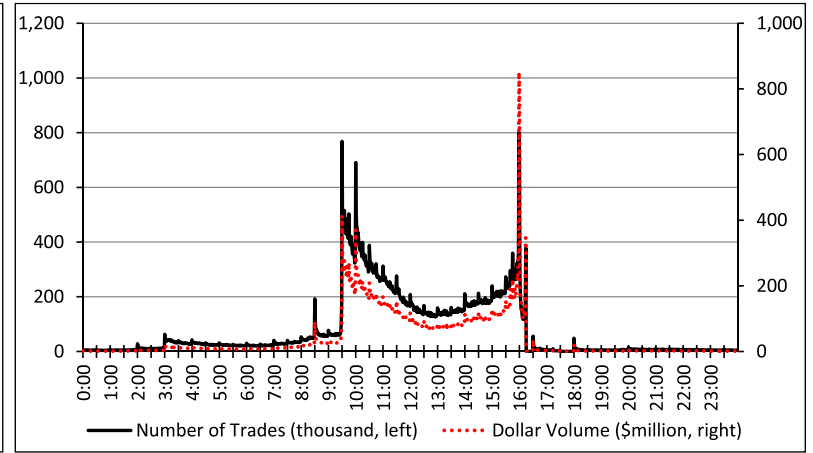
(b) ANN=0
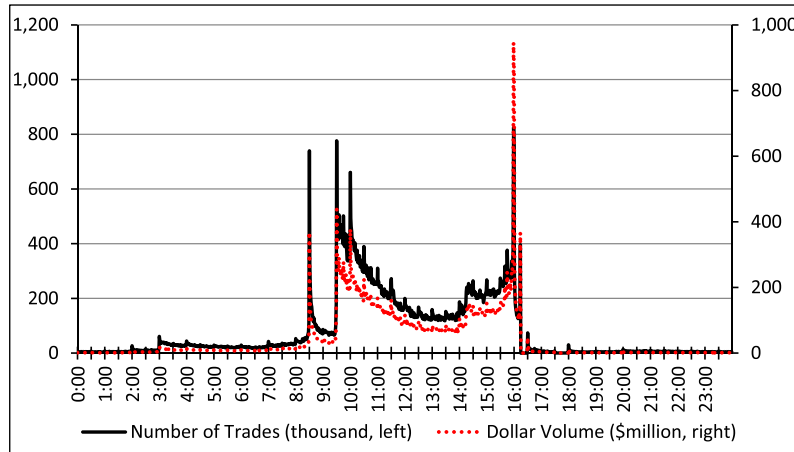
(c) SUR=0
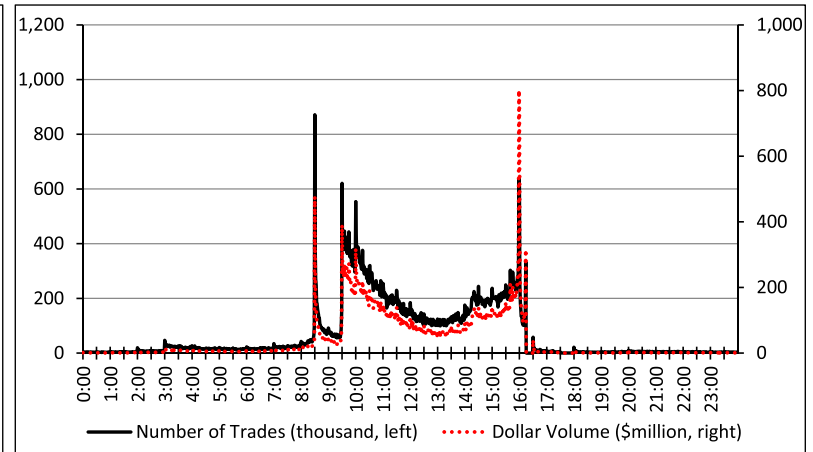
(d) SUR=1

Figure 5: Intraday liquidity in the E-mini S&P 500 futures

This figure plots the minute-by-minute number of trades and dollar volume in the E-mini S&P 500 futures. The black solid line is the average number of trades (left axis) and the red dashed lines is the average dollar volume (right axis). Panels A, B, C, and D correspond to all trading days (Full sample), the control days (ANN=0), the non-surprise announcement days (SUR=0), and the surprise announcement days (SUR=1), respectively.

Table 1: Information about macroeconomic announcements

The table provides the basic information about the four types of macroeconomic announcements in this study. FOMC, DOL, and BEA stand for the Federal Open Market Committee, the Department of Labor, and the Bureau of Economic Analysis, respectively.

Announcement	Source	Frequency	Type	Units	Release time
Federal funds target rate	FOMC	8 per year	Level	Percent (%)	2:15 p.m. (occasionally 12:30 p.m. or 2 p.m.)
Nonfarm payrolls	DOL	Monthly	Change	Thousands	8:30 a.m.
CPI	DOL	Monthly	Change	Percent (%)	8:30 a.m.
GDP	BEA	Monthly	Change	Percent (%)	8:30 a.m.

Table 2: Summary statistics of the announcement surprise

The table presents the statistics of the difference between the expected (Exp) and actual (Act) macroeconomic indicators between September 9, 1997 and June 30, 2013. Diff is calculated as Act minus Exp and AbsDiff is the absolute value of Diff. The expected Federal funds target rate is the volume-weighted implied rate from the CME Federal funds futures at one day before the announcement date. The expected values of nonfarm payroll, CPI, and GDP are the median of the economist forecasts from the Blue Chip Economic Indicators Survey.

Statistics	N	Mean	St. dev.	Median	Minimum	Maximum
Panel A: FOMC						
Exp	127	2.767	2.231	2.105	0.071	6.572
Act	127	2.713	2.244	2.000	0.125	6.500
Diff	127	-0.054	0.131	-0.050	-0.450	0.455
AbsDiff	127	0.104	0.097	0.083	0.000	0.455
Panel B: Nonfarm payroll						
Exp	189	82.185	181.112	125	-650	513
Act	189	63.820	201.633	94	-663	519
Diff	189	-18.365	95.911	-13	-330	459
AbsDiff	189	70.841	67.029	59	0	459
Panel C: CPI						
Exp	189	0.204	0.244	0.200	-1.200	0.900
Act	189	0.192	0.325	0.200	-1.700	1.200
Diff	189	-0.012	0.142	0.000	-0.700	0.400
AbsDiff	189	0.101	0.100	0.100	0.000	0.700
Panel D: GDP						
Exp	189	2.583	2.293	2.800	-6.500	8.200
Act	189	2.560	2.352	2.700	-6.300	8.200
Diff	189	-0.023	0.559	0.000	-3.400	1.600
AbsDiff	189	0.369	0.420	0.200	0.000	3.400

Table 3: Annual breakdown of macro announcements

The table presents the time-series distribution of macroeconomic announcements classified as surprise or no surprise to the market from September 9, 1997 to June 30, 2013. A FOMC announcement is defined as a surprise (SUR=1) if the actual announced target rate deviates from the futures-implied rate by at least 12.5 basis points. For the other types of macroeconomic indicators, an event is classified as a surprise (SUR=1) if the actual value is outside the 10th to 90th percentiles of the economist forecasts from the Blue Chip Economic Indicators Survey.

	FOMC		Nonfarm payroll		CPI		GDP	
Year	SUR=0	SUR=1	SUR=0	SUR=1	SUR=0	SUR=1	SUR=0	SUR=1
1997	2	1	2	1	1	3	4	0
1998	9	0	9	3	5	7	6	6
1999	6	2	8	4	7	5	8	3
2000	6	2	7	5	9	2	7	5
2001	7	2	7	5	10	2	9	3
2002	6	2	12	0	11	1	8	4
2003	7	0	9	3	5	7	8	4
2004	4	4	5	7	7	5	8	4
2005	1	7	9	3	7	5	11	1
2006	7	1	9	3	9	3	9	3
2007	7	1	10	2	12	0	10	2
2008	5	3	6	6	7	5	8	4
2009	7	0	6	6	9	3	8	4
2010	8	0	7	5	11	1	11	1
2011	8	0	7	5	8	4	11	1
2012	8	0	12	0	11	1	9	3
2013	4	0	5	1	3	3	2	4
SUM	102	25	130	59	132	57	137	52
Total	127		189		189		189	

Table 4: Description of the E-mini S&P500 market around the announcement

This table reports the summary statistics of the cumulative returns and order imbalances of the E-mini S&P500 futures around the macroeconomic announcement. For each macroeconomic announcement, the previous 21 trading days are used as control days (ANN=0). In Panel A, a FOMC announcement is defined as a surprise (SUR=1) if the actual announced target rate deviates from the futures-implied rate by at least 12.5 basis points. For the other types macroeconomic announcements in Panels B, C, and D, an event is classified as a surprise (SUR=1) if the actual value is outside the 10th to 90th percentiles of the economist forecasts from the Blue Chip Economic Indicators Survey. The E-mini S&P 500 futures data from the Chicago Mercantile Exchange (CME) are used to calculate the variables of interest. Return is the cumulative return in basis point calculated using volume-weighted transaction prices. OIN represents the order imbalance defined as B-S/(B+S), where B (S) is the number of trades initiated by the buyer (seller). OID is calculated similarly to OIN using dollar trading volume instead of number of trades. Three event periods are examined around the announcement: [-60,-30], from one hour before to half an hour before; [-30,0], from half hour before to the official release time; and [0,60], from the official release time to one hour afterwards. For observations in the surprise announcement group (SUR=1), the signs of the return and order imbalance variables are adjusted to reflect the effects of a market-positive surprise.

		Mean			Standard deviation			Median		
	Period	Return	OIN	OID	Return	OIN	OID	Return	OIN	OID
Panel A: FOMC										
ANN=0	[-60,-30]	0.711	0.052	-0.363	24.967	11.712	14.320	0.580	0.000	-0.638
	[-30,0]	-1.067	-0.569	-0.621	24.650	10.023	12.939	-0.042	-0.485	-0.879
	[0,60]	1.421	-0.116	-0.084	43.278	6.506	9.101	1.052	-0.138	-0.443
SUR=0	[-60,-30]	0.808	-0.683	0.678	16.796	11.454	15.031	-0.876	0.318	1.182
	[-30,0]	-4.385	-0.500	-0.208	22.164	9.997	11.330	-2.593	-0.707	0.378
	[0,60]	8.463	-0.621	-0.077	69.436	4.116	6.441	10.212	-0.326	0.492
SUR=1	[-60,-30]	-0.276	-0.790	-4.494	15.019	12.077	19.150	-2.813	1.038	-2.492
	[-30,0]	16.128	7.913	9.268	24.768	11.208	13.538	11.439	9.034	8.680
	[0,60]	5.141	-0.313	0.066	99.257	4.387	7.934	-2.883	-0.629	-0.927
Panel B: Nonfarm Payroll										
ANN=0	[-60,-30]	-0.060	0.559	0.669	14.921	21.416	26.203	0.038	0.000	0.059
	[-30,0]	0.173	0.107	0.496	17.346	16.197	20.891	0.010	0.000	0.064
	[0,60]	-1.800	-1.324	-1.496	26.614	10.684	14.249	-1.648	-1.055	-1.376
SUR=0	[-60,-30]	0.573	0.109	1.066	9.972	19.612	23.718	0.000	0.262	0.873
	[-30,0]	5.986	2.475	4.641	13.688	11.778	14.030	6.030	2.583	2.963
	[0,60]	5.305	0.152	1.147	53.624	6.861	10.740	6.728	0.062	0.390
SUR=1	[-60,-30]	1.359	-4.340	-2.850	16.757	18.700	24.259	0.000	-1.653	-4.166
	[-30,0]	0.054	-1.037	-0.619	21.659	12.554	16.445	-1.916	-0.008	0.145
	[0,60]	27.196	0.042	2.170	68.281	7.004	8.835	30.775	0.966	4.809

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Table 4 (continued):

		Mean			Standard deviation			Median		
	Period	Return	OIN	OID	Return	OIN	OID	Return	OIN	OID
Panel C: CPI										
ANN=0	[-60,-30]	-0.053	0.656	0.773	14.872	21.330	26.122	0.035	0.000	0.264
	[-30,0]	0.126	0.102	0.480	17.371	16.284	20.905	0.000	0.000	0.053
	[0,60]	-1.764	-1.342	-1.477	26.647	10.695	14.241	-1.648	-1.065	-1.352
SUR=0	[-60,-30]	-1.933	-0.409	0.996	14.981	18.349	22.650	-0.394	-2.134	-1.529
	[-30,0]	2.987	2.121	3.171	12.945	15.006	17.631	1.300	0.510	3.952
	[0,60]	2.193	-0.393	0.009	33.550	7.841	11.213	-1.373	-0.901	-0.085
SUR=1	[-60,-30]	-1.440	-1.820	-3.554	15.453	22.901	29.482	0.000	-2.564	-1.778
	[-30,0]	2.477	0.046	1.210	16.574	14.290	17.129	1.346	1.238	0.754
	[0,60]	14.055	1.312	2.421	43.557	8.660	12.280	9.727	0.683	2.369
Panel D: GDP										
ANN=0	[-60,-30]	-0.062	0.575	0.688	14.954	21.238	26.001	0.043	0.000	0.162
	[-30,0]	0.082	0.061	0.400	17.415	16.267	20.875	0.000	0.000	0.018
	[0,60]	-1.745	-1.342	-1.486	26.585	10.675	14.188	-1.639	-1.055	-1.352
SUR=0	[-60,-30]	0.448	0.745	2.851	14.650	18.739	25.097	0.000	0.429	1.721
	[-30,0]	4.408	1.539	3.426	18.989	14.847	20.133	2.698	0.680	3.544
	[0,60]	-0.542	0.243	0.168	29.258	9.030	12.875	-3.910	-0.156	-0.996
SUR=1	[-60,-30]	-1.185	1.390	1.049	14.960	20.750	24.124	-1.079	2.227	0.826
	[-30,0]	2.358	1.083	1.654	15.355	10.974	17.625	3.005	2.181	5.500
	[0,60]	21.826	3.591	5.917	51.689	6.909	8.527	14.327	2.419	4.339

Table 5: OLS regressions on announcement type dummies

This table presents OLS regression results in the E-mini S&P 500 futures market. The dependent variables are the returns and order imbalances calculated using both number of trades and dollar volume in three event windows: [-60,-30], [-30,0], and [0,60]. For observations in the surprise announcement group, the signs of the return and order imbalance variables are adjusted to reflect the effects of a market-positive surprise. Panels A to D report separate regression results for announcements on the Federal funds target rate, nonfarm payroll, CPI, and GDP, respectively. Variables ANN and SUR are defined in Table 4. Corresponding t-statistics are reported in parentheses. The last row of each panel reports the p-value of the Wald test that the sum of the coefficients of ANN and SUR equals to zero.

Period	[-60,-30]			[-30,0]			[0,60]		
Model	1	2	3	4	5	6	7	8	9
Dependent	Ret	OIN	OID	Ret	OIN	OID	Ret	OIN	OID
Panel A: FOMC									
Intercept	0.711	0.059	-0.363	-1.067	-0.567	-0.621	1.422	-0.115	-0.084
	(1.43)	(0.25)	(-1.25)	(-2.15)	(-2.80)	(-2.39)	(1.55)	(-0.89)	(-0.46)
ANN	0.096	-0.742	1.041	-3.318	0.066	0.413	7.041	-0.506	0.008
	(0.04)	(-0.63)	(0.72)	(-1.34)	(0.07)	(0.32)	(1.53)	(-0.78)	(0.01)
SUR	-1.083	-0.107	-5.172	20.513	8.413	9.476	-3.322	0.308	0.142
	(-0.2)	(-0.04)	(-1.61)	(3.74)	(3.76)	(3.30)	(-0.33)	(0.22)	(0.07)
ANN+SUR	-0.987	-0.850	-4.131	17.195	8.480	9.889	3.719	-0.198	0.150
p-value	0.8420	0.7180	0.1537	0.0005	< 0.0001	0.0001	0.6838	0.8783	0.9340
Panel B: Nonfarm payroll									
Intercept	-0.060	0.559	0.669	0.173	0.107	0.496	-1.800	-1.324	-1.496
	(-0.23)	(1.50)	(1.46)	(0.57)	(0.38)	(1.37)	(-3.51)	(-7.19)	(-6.07)
ANN	0.634	-0.450	0.396	5.813	2.368	4.145	7.105	1.475	2.642
	(0.48)	(-0.24)	(0.17)	(3.76)	(1.66)	(2.25)	(2.72)	(1.57)	(2.10)
SUR	0.786	-4.448	-3.916	-5.933	-3.512	-5.260	21.890	-0.109	1.024
	(0.34)	(-1.33)	(-0.96)	(-2.18)	(-1.40)	(-1.63)	(4.77)	(-0.07)	(0.46)
ANN+SUR	1.419	-4.899	-3.520	-0.120	-1.144	-1.115	28.996	1.366	3.666
p-value	0.4654	0.0802	0.3043	0.9580	0.5862	0.6804	<0.0001	0.3227	0.0472

Table 5 (continued):

Period	[-60,-30]			[-30,0]			[0,60]		
Model	1	2	3	4	5	6	7	8	9
Dependent	Ret	OIN	OID	Ret	OIN	OID	Ret	OIN	OID
Panel C: CPI									
Intercept	-0.053	0.656	0.773	0.126	0.102	0.480	-1.764	-1.342	-1.477
	(-0.20)	(1.77)	(1.70)	(0.42)	(0.36)	(1.32)	(-3.70)	(-7.27)	(-5.99)
ANN	-1.879	-1.065	0.223	2.861	2.018	2.692	3.957	0.949	1.486
	(-1.42)	(-0.56)	(0.10)	(1.87)	(1.40)	(1.46)	(1.63)	(1.01)	(1.19)
SUR	0.493	-1.411	-4.550	-0.510	-2.075	-1.961	11.863	1.705	2.412
	(0.21)	(-0.42)	(-1.10)	(-0.19)	(-0.81)	(-0.60)	(2.74)	(1.02)	(1.08)
ANN+SUR	-1.387	-2.476	-4.327	2.351	-0.056	0.730	15.820	2.654	3.898
p-value	0.4857	0.3833	0.2140	0.3066	0.9792	0.7921	<0.0001	0.0602	0.0387
Panel D: GDP									
Intercept	-0.062	0.575	0.688	0.082	0.061	0.400	-1.745	-1.342	-1.486
	(-0.24)	(1.55)	(1.51)	(0.27)	(0.22)	(1.10)	(-3.65)	(-7.24)	(-6.02)
ANN	0.509	0.170	2.163	4.326	1.478	3.026	1.203	1.585	1.654
	(0.39)	(0.09)	(0.96)	(2.84)	(1.05)	(1.67)	(0.51)	(1.72)	(1.35)
SUR	-1.632	0.645	-1.802	-2.050	-0.456	-1.771	22.368	3.347	5.749
	(-0.67)	(0.19)	(-0.43)	(-0.72)	(-0.17)	(-0.52)	(5.04)	(1.94)	(2.51)
ANN+SUR	-1.123	0.815	0.361	2.276	1.022	1.254	23.571	4.933	7.403
p-value	0.5908	0.7827	0.9207	0.3508	0.6507	0.6662	<0.0001	0.0008	0.0002

Table 6: Information leakage effect before and after 2006

This table presents OLS regression results in the E-mini S&P 500 futures market over subperiods before and after 2006. The dependent variables are the returns and order imbalances calculated using both number of trades and dollar volume in three event windows: [-60,-30], [-30,0], and [0,60]. For observations in the surprise announcement group, the signs of the return and order imbalance variables are adjusted to reflect the effects of a market-positive surprise. Panels A to D report separate regression results for announcements on the Federal funds target rate, nonfarm payroll, CPI, and GDP, respectively. Post is a dummy equal to one for observations after January 1, 2006 and zero otherwise. Variables ANN and SUR are defined in Table 4. Corresponding t-statistics are reported in parentheses. The last row of each panel reports the p-value of the Wald test that the sum of the coefficients of ANN*Post and SUR*Post equals to zero.

Period	[-60,-30]			[-30,0]			[0,60]		
Model	1	2	3	4	5	6	7	8	9
Dependent	Ret	OIN	OID	Ret	OIN	OID	Ret	OIN	OID
Panel A: FOMC									
Intercept	1.224	-0.402	-0.934	-0.699	-0.586	-0.931	-0.196	-0.288	-0.788
	(1.78)	(-1.24)	(-2.33)	(-1.02)	(-2.09)	(-2.59)	(-0.16)	(-1.61)	(-3.15)
ANN	-0.465	-1.946	0.858	-6.072	-0.524	-0.243	-7.898	-1.142	-1.262
	(-0.13)	(-1.13)	(0.41)	(-1.68)	(-0.36)	(-0.13)	(-1.19)	(-1.21)	(-0.96)
SUR	-1.069	3.591	-2.905	19.347	10.247	10.702	20.982	1.251	2.573
	(-0.16)	(1.15)	(-0.76)	(2.96)	(3.84)	(3.12)	(1.74)	(0.73)	(1.08)
Post	-1.078	0.972	1.202	-0.776	0.040	0.654	3.408	0.364	1.483
	(-1.08)	(2.06)	(2.07)	(-0.78)	(0.10)	(1.25)	(1.86)	(1.40)	(4.09)
ANN*Post	1.171	2.173	0.222	5.281	1.111	1.173	27.867	1.164	2.246
	(0.23)	(0.92)	(0.08)	(1.06)	(0.55)	(0.45)	(3.04)	(0.90)	(1.24)
SUR*Post	0.082	-13.310	-8.987	13.249	-7.273	-3.123	-70.012	-2.198	-6.013
	(0.01)	(-2.12)	(-1.16)	(1.00)	(-1.35)	(-0.45)	(-2.87)	(-0.64)	(-1.25)
(ANN+SUR)*Post	1.254	-11.136	-8.766	18.530	-6.162	-1.950	-42.145	-1.034	-3.767
p-value	0.9192	0.0576	0.2249	0.1327	0.2211	0.7630	0.0637	0.7479	0.4025
Panel B: Nonfarm payroll									
Intercept	0.651	1.548	2.158	0.183	0.447	0.813	-2.510	-1.581	-2.082
	(1.82)	(3.01)	(3.43)	(0.44)	(1.16)	(1.63)	(-3.57)	(-6.23)	(-6.14)
ANN	-1.092	-1.582	-1.726	5.849	3.750	5.039	8.623	2.399	2.859
	(-0.60)	(-0.60)	(-0.54)	(2.73)	(1.90)	(1.98)	(2.39)	(1.85)	(1.65)
SUR	2.318	-8.074	-4.083	-7.878	-5.566	-7.216	4.610	-0.164	0.183
	(0.72)	(-1.75)	(-0.72)	(-2.10)	(-1.61)	(-1.62)	(0.73)	(-0.07)	(0.06)
Post	-1.502	-2.089	-3.146	-0.020	-0.719	-0.670	1.501	0.544	1.240
	(-2.89)	(-2.79)	(-3.44)	(-0.03)	(-1.28)	(-0.93)	(1.47)	(1.48)	(2.51)
ANN*Post	3.630	2.389	4.474	-0.075	-2.891	-1.869	-3.196	-1.942	-0.464
	(1.37)	(0.63)	(0.96)	(-0.02)	(-1.01)	(-0.51)	(-0.61)	(-1.03)	(-0.18)
SUR*Post	-3.218	7.640	0.358	4.099	4.309	4.108	36.403	0.108	1.776
	(-0.69)	(1.14)	(0.04)	(0.75)	(0.86)	(0.63)	(3.97)	(0.03)	(0.40)
(ANN+SUR)*Post	0.411	10.030	4.832	4.024	1.418	2.240	33.208	-1.834	1.311
p-value	0.4654	0.0802	0.3043	0.958	0.5862	0.6804	<0.0001	0.3227	0.0472

Table 6 (continued):

Period	[-60,-30]			[-30,0]			[0,60]		
Model	1	2	3	4	5	6	7	8	9
Dependent	Ret	OIN	OID	Ret	OIN	OID	Ret	OIN	OID
Panel C: CPI									
Intercept	0.708	1.757	2.380	0.184	0.484	0.847	-2.550	-1.583	-2.081
	(1.97)	(3.42)	(3.78)	(0.44)	(1.24)	(1.69)	(-3.87)	(-6.20)	(-6.11)
ANN	-2.118	-1.533	-0.747	4.169	4.370	3.883	3.655	1.631	1.095
	(-1.10)	(-0.56)	(-0.22)	(1.87)	(2.09)	(1.45)	(1.04)	(1.19)	(0.60)
SUR	1.162	-3.154	-5.787	-2.895	-5.393	-4.853	13.48	0.913	2.999
	(0.38)	(-0.72)	(-1.07)	(-0.81)	(-1.60)	(-1.13)	(2.38)	(0.42)	(1.02)
Post	-1.592	-2.303	-3.363	-0.122	-0.799	-0.768	1.646	0.505	1.264
	(-3.06)	(-3.10)	(-3.69)	(-0.20)	(-1.41)	(-1.06)	(1.72)	(1.37)	(2.56)
ANN*Post	0.606	1.109	2.160	-2.454	-4.355	-2.171	0.406	-1.336	0.611
	(0.23)	(0.29)	(0.47)	(-0.80)	(-1.51)	(-0.59)	(0.08)	(-0.71)	(0.24)
SUR*Post	-2.410	4.356	2.911	5.480	6.821	6.737	-3.561	1.833	-0.715
	(-0.49)	(0.63)	(0.34)	(0.97)	(1.28)	(0.99)	(-0.40)	(0.53)	(-0.15)
(ANN+SUR)*Post	-1.803	5.465	5.071	3.026	2.466	4.566	-3.155	0.498	-0.103
p-value	0.4857	0.3833	0.2140	0.3066	0.9792	0.7921	<0.0001	0.0602	0.0387
Panel D: GDP									
Intercept	0.647	1.521	2.075	0.087	0.428	0.680	-2.508	-1.607	-2.129
	(1.79)	(2.97)	(3.30)	(0.21)	(1.09)	(1.35)	(-3.80)	(-6.27)	(-6.24)
ANN	1.118	2.084	3.795	4.909	3.875	6.740	0.717	2.817	2.831
	(0.61)	(0.80)	(1.19)	(2.29)	(1.95)	(2.64)	(0.21)	(2.17)	(1.64)
SUR	0.615	0.083	-2.053	-2.195	-2.695	-2.725	24.804	3.982	6.585
	(0.19)	(0.02)	(-0.36)	(-0.57)	(-0.76)	(-0.60)	(4.16)	(1.72)	(2.14)
Post	-1.485	-1.982	-2.906	-0.011	-0.770	-0.586	1.599	0.555	1.348
	(-2.83)	(-2.67)	(-3.19)	(-0.02)	(-1.36)	(-0.80)	(1.67)	(1.50)	(2.73)
ANN*Post	-1.170	-3.780	-3.177	-1.174	-4.799	-7.460	0.915	-2.504	-2.425
	(-0.45)	(-1.03)	(-0.70)	(-0.39)	(-1.70)	(-2.06)	(0.19)	(-1.36)	(-0.99)
SUR*Post	-5.770	0.330	-0.461	0.139	4.330	0.861	-5.322	-1.838	-2.163
	(-1.18)	(0.05)	(-0.05)	(0.02)	(0.82)	(0.13)	(-0.59)	(-0.53)	(-0.47)
(ANN+SUR)*Post	-6.940	-3.450	-3.638	-1.036	-0.470	-6.599	-4.407	-4.342	-4.588
p-value	0.5908	0.7827	0.9207	0.3508	0.6507	0.6662	<0.0001	0.0008	0.0002

Table 7: Alternative surprise definitions

This table presents OLS regression results in the E-mini S&P 500 futures market with alternative surprise definitions for FOMC announcements. The dependent variables are the returns and order imbalances calculated using both number of trades and dollar volume in three event windows: [-60,-30], [-30,0], and [0,60]. For observations in the surprise announcement group, the signs of the return and order imbalance variables are adjusted to reflect the effects of a market-positive surprise. In Panel A, SUR is euqal to one when the actual announced target rate deviates from the futures-implied rate by at least 17.5 basis points. In Panel B, SUR is euqal to one when the actual announced target rate deviates from the futures-implied rate by at least 20 basis points. In Panel C, AbsDiff is the absolute value of the difference between the expected and actual Federal funds target rates. Corresponding t-statistics are reported in parentheses. The last row of Panels A and B reports the p-value of the Wald test that the sum of the coefficients of ANN and SUR equals to zero.

Period	[-60,-30]			[-30,0]			[0,60]		
Model	1	2	3	4	5	6	7	8	9
Dependent	Ret	OIN	OID	Ret	OIN	OID	Ret	OIN	OID
Panel A: SUR=1 if AbsDiff>17.5 bp, 22 observations									
Intercept	0.711	0.059	-0.363	-1.067	-0.567	-0.621	1.422	-0.115	-0.084
	(1.43)	(0.25)	(-1.25)	(-2.15)	(-2.79)	(-2.38)	(1.55)	(-0.89)	(-0.46)
ANN	-0.118	-1.076	0.445	-2.230	0.549	0.978	8.259	-0.451	0.177
	(-0.05)	(-0.93)	(0.31)	(-0.92)	(0.55)	(0.77)	(1.84)	(-0.71)	(0.20)
SUR	0.005	1.983	-2.679	18.729	7.451	8.262	-11.885	0.039	-0.896
	(0.00)	(0.70)	(-0.76)	(3.13)	(3.05)	(2.63)	(-1.07)	(0.02)	(-0.41)
ANN+SUR	-0.113	0.907	-2.235	16.500	8.001	9.240	-3.626	-0.412	-0.719
p-value	0.9837	0.7299	0.4897	0.0028	0.0004	0.0014	0.7221	0.7747	0.7219
Panel B: SUR=1 if AbsDiff>20 bp, 18 observations									
Intercept	0.711	0.059	-0.363	-1.067	-0.567	-0.621	1.422	-0.115	-0.084
	(1.43)	(0.25)	(-1.25)	(-2.15)	(-2.79)	(-2.38)	(1.55)	(-0.89)	(-0.46)
ANN	0.233	-0.781	0.408	-1.870	0.668	1.173	8.666	-0.377	0.290
	(0.10)	(-0.68)	(0.29)	(-0.78)	(0.68)	(0.93)	(1.96)	(-0.60)	(0.33)
SUR	-2.612	0.128	-2.880	19.351	7.879	8.259	-17.026	-0.512	-1.899
	(-0.41)	(0.04)	(-0.77)	(3.02)	(3.01)	(2.46)	(-1.44)	(-0.31)	(-0.81)
ANN+SUR	-2.379	-0.653	-2.472	17.480	8.547	9.432	-8.360	-0.888	-1.609
p-value	0.6914	0.8187	0.4809	0.0035	0.0005	0.0027	0.4495	0.5694	0.4627
Panel C: Use actual difference instead of dummy									
Intercept	0.711	0.059	-0.363	-1.068	-0.567	-0.621	1.424	-0.115	-0.084
	(1.43)	(0.25)	(-1.25)	(-2.15)	(-2.80)	(-2.39)	(1.55)	(-0.89)	(-0.46)
ANN	0.307	-1.043	0.596	-3.417	-0.324	0.389	13.005	-0.291	0.765
	(0.11)	(-0.78)	(0.36)	(-1.22)	(-0.28)	(0.26)	(2.51)	(-0.40)	(0.75)
AbsDiff	-5.436	3.584	-7.344	53.027	26.230	24.223	-84.839	-1.970	-9.355
	(-0.25)	(0.35)	(-0.58)	(2.44)	(2.96)	(2.13)	(-2.12)	(-0.35)	(-1.18)

Table 8: Alternative surprise definitions for the QE period

This table presents OLS regression results in the E-mini S&P 500 futures market with alternative surprise definitions for FOMC announcements during the Quantitative Easing (QE) period. The dependent variables are the returns and order imbalances calculated using both number of trades and dollar volume in three event windows: [-60,-30], [-30,0], and [0,60]. For observations in the surprise announcement group, the signs of the return and order imbalance variables are adjusted to reflect the effects of a market-positive surprise. In Panel A, we use the mean of the target range and the 12.5 bp threshold to define surprise in the QE period. For the rest of the sample period, we use the same definition as in Table 5. In Panel B, we use the realized rate changes in the 10-year treasury to define surprise. SUR is euqal to one if the magnitude of the realized rate change on the announcement day exceeds 1.75 times the its standard error calculated using data from 10 days before and 10 days after each announcement. Corresponding t-statistics are reported in parentheses. The last row of each panel reports the p-value of the Wald test that the sum of the coefficients of ANN and SUR equals to zero.

Period	[-60,-30]			[-30,0]			[0,60]		
Model	1	2	3	4	5	6	7	8	9
Dependent	Ret	OIN	OID	Ret	OIN	OID	Ret	OIN	OID
Panel A: Using the mean of target range as the target rate, 38 observations									
Intercept	0.706	0.057	-0.372	-1.062	-0.556	-0.611	1.470	-0.113	-0.080
	(1.42)	(0.24)	(-1.28)	(-2.14)	(-2.74)	(-2.35)	(1.60)	(-0.88)	(-0.44)
ANN	-0.683	-0.750	1.368	-4.392	-0.547	-0.224	6.122	-0.536	-0.255
	(-0.26)	(-0.60)	(0.89)	(-1.67)	(-0.51)	(-0.16)	(1.26)	(-0.78)	(-0.26)
SUR	2.301	0.169	-3.928	16.833	6.885	7.718	-2.556	0.193	0.681
	(0.48)	(0.07)	(-1.41)	(3.54)	(3.54)	(3.10)	(-0.29)	(0.16)	(0.39)
ANN+SUR	1.618	-0.580	-2.560	12.440	6.339	7.494	3.566	-0.343	0.426
p-value	0.6878	0.7616	0.2770	0.0020	0.0001	0.0004	0.6311	0.7433	0.7723
Panel B: Using realized rate change, 31 observations									
Intercept	0.706	0.057	-0.372	-1.062	-0.556	-0.611	1.470	-0.113	-0.080
	(1.42)	(0.24)	(-1.28)	(-2.14)	(-2.74)	(-2.35)	(1.60)	(-0.88)	(-0.44)
ANN	0.484	-0.405	1.589	-2.913	-0.134	0.438	3.814	-0.656	-0.194
	(0.19)	(-0.33)	(1.07)	(-1.14)	(-0.13)	(0.33)	(0.81)	(-0.99)	(-0.21)
SUR	-1.061	1.158	-4.307	13.564	7.335	7.521	8.059	0.366	0.547
	(-0.21)	(0.48)	(-1.45)	(2.67)	(3.54)	(2.83)	(0.86)	(0.28)	(0.29)
ANN+SUR	-0.577	0.753	-2.718	10.650	7.201	7.959	11.874	-0.290	0.352
p-value	0.8969	0.7219	0.2965	0.0167	<.0001	0.0006	0.1482	0.8025	0.8285

Table 9: Activities around FOMC announcements in other markets

In this table, we repeat our analysis for FOMC announcements with alternative testing securities. Panels A, B, and C report the results on the E-mini Nasdaq 100 futures, SPDR S&P 500 ETF, and PowerShares QQQ ETF (tracking Nasdaq 100), respectively. The dependent variables are the returns and order imbalances calculated using both number of trades and dollar volume in three event windows: [-60,-30], [-30,0], and [0,60]. For observations in the surprise announcement group, the signs of the return and order imbalance variables are adjusted to reflect the effects of a market-positive surprise. Variables ANN and SUR are defined in Table 4. Corresponding t-statistics are reported in parentheses. The last row of each panel reports the p-value of the Wald test that the sum of the coefficients of ANN and SUR equals to zero.

Period	[-60,-30]			[-30,0]			[0,60]		
Model	1	2	3	4	5	6	7	8	9
Dependent	Ret	OIN	OID	Ret	OIN	OID	Ret	OIN	OID
Panel A: E-mini Nasdaq 100 futures									
Intercept	1.740	-0.310	-0.216	-1.849	-0.185	-0.369	0.895	0.165	-0.044
	(1.35)	(-1.03)	(-0.52)	(-1.66)	(-0.72)	(-1.02)	(0.44)	(0.97)	(-0.17)
ANN	3.455	-1.226	0.217	-8.656	2.594	1.109	7.305	-0.814	-0.016
	(0.50)	(-0.75)	(0.10)	(-1.44)	(1.86)	(0.57)	(0.67)	(-0.89)	(-0.01)
SUR	-5.430	2.625	-1.646	29.525	1.531	7.284	39.512	1.894	1.449
	(-0.44)	(0.92)	(-0.42)	(2.80)	(0.63)	(2.13)	(2.07)	(1.18)	(0.60)
ANN+SUR	-1.975	1.399	-1.429	20.869	4.124	8.393	46.817	1.081	1.434
p-value	0.8464	0.5566	0.6628	0.0177	0.0432	0.0034	0.0033	0.4196	0.4738
Panel B: SPDR S&P 500 ETF									
Intercept	0.535	2.078	-0.386	-1.050	1.462	-0.367	0.434	1.992	-0.193
	(0.94)	(5.00)	(-0.50)	(-1.89)	(3.72)	(-0.50)	(0.42)	(6.46)	(-0.35)
ANN	-0.092	2.266	7.265	-2.311	1.888	8.921	4.068	-1.124	-1.662
	(-0.03)	(1.03)	(1.77)	(-0.79)	(0.91)	(2.31)	(0.75)	(-0.69)	(-0.58)
SUR	-5.129	-6.798	-3.597	20.504	8.004	-4.975	9.794	0.633	1.940
	(-0.90)	(-1.64)	(-0.47)	(3.71)	(2.05)	(-0.69)	(0.96)	(0.21)	(0.36)
ANN+SUR	-5.221	-4.532	3.668	18.193	9.892	3.947	13.862	-0.491	0.278
p-value	0.2845	0.2019	0.5791	0.0001	0.0032	0.5265	0.1125	0.8519	0.9523
Panel C: PowerShares QQQ ETF (tracking Nasdaq 100)									
Intercept	1.806	0.608	0.232	-1.929	-0.495	-0.215	0.505	-0.407	-1.239
	(1.36)	(1.30)	(0.37)	(-1.77)	(-1.12)	(-0.36)	(0.26)	(-1.16)	(-2.59)
ANN	3.621	1.512	1.807	-9.495	-0.045	-4.976	6.766	-0.657	0.410
	(0.50)	(0.60)	(0.53)	(-1.61)	(-0.02)	(-1.54)	(0.64)	(-0.35)	(0.16)
SUR	-6.442	0.389	-3.096	32.280	7.393	11.464	40.121	6.887	6.420
	(-0.50)	(0.09)	(-0.52)	(3.09)	(1.74)	(2.00)	(2.15)	(2.05)	(1.40)
ANN+SUR	-2.821	1.901	-1.289	22.785	7.348	6.488	46.886	6.231	6.830
p-value	0.7924	0.6154	0.7983	0.0094	0.0397	0.1774	0.0028	0.0274	0.0762

Table 10: Further investigation into the lockup window

This table presents OLS regression results for FOMC announcements. The dependent variables are the returns and order imbalances calculated using both number of trades and dollar volume in three sub-windows of the lockup period: [-30,-20], from half hour before to twenty minutes before; [-20,-10], from twenty minutes before to ten minutes before; and [-10, 0], from ten minutes before to the minute before the announcement. For observations in the surprise announcement group, the signs of the return and order imbalance variables are adjusted to reflect the effects of a market-positive surprise. In Panels A and B, we repeat the analysis in Table 5 and 6 on E-mini S&P 500 futures. Panels C, D, and E repeat our analysis in Table 9 on the E-mini Nasdaq 100 futures, SPDR S&P 500 ETF, and PowerShares QQQ ETF, respectively. Corresponding t-statistics are reported in parentheses. Corresponding t-statistics are reported in parentheses. The last row of each panel reports the p-value of the Wald test that the sum of the coefficients of ANN and SUR equals to zero.

Period	[-30,-20]			[-20,-10]			[-10,0]		
Model	1	2	3	4	5	6	7	8	9
Dependent	Ret	OIN	OID	Ret	OIN	OID	Ret	OIN	OID
Panel A: Sub-windows during the lockup period									
Intercept	-0.531	-0.591	-0.793	-0.230	-0.597	-0.674	-0.303	-0.782	-0.967
	(-1.80)	(-1.76)	(-1.94)	(-0.76)	(-1.77)	(-1.63)	(-0.99)	(-2.37)	(-2.47)
ANN	0.623	-1.076	-0.757	-0.088	1.248	0.326	-3.847	1.194	2.325
	(0.42)	(-0.64)	(-0.37)	(-0.06)	(0.74)	(0.16)	(-2.50)	(0.72)	(1.19)
SUR	-0.315	4.444	5.725	2.950	7.551	10.591	17.875	6.267	6.964
	(-0.10)	(1.20)	(1.27)	(0.88)	(2.02)	(2.32)	(5.25)	(1.72)	(1.61)
ANN+SUR	0.308	3.368	4.968	2.862	8.798	10.917	14.027	7.460	9.289
p-value	0.9167	0.3146	0.2217	0.341	0.0089	0.0079	<.0001	0.0232	0.0171
Panel B: Sub-windows before and after 2006									
Intercept	-0.324	-1.095	-1.817	0.301	0.012	-0.386	-0.673	-1.067	-1.241
	(-0.79)	(-2.36)	(-3.23)	(0.72)	(0.03)	(-0.68)	(-1.59)	(-2.35)	(-2.30)
ANN	2.296	0.441	0.567	-0.036	-0.258	-0.437	-8.324	-0.461	0.278
	(1.07)	(0.18)	(0.19)	(-0.02)	(-0.10)	(-0.15)	(-3.72)	(-0.19)	(0.10)
SUR	-2.582	4.328	5.329	2.214	8.146	10.644	19.705	9.945	10.124
	(-0.66)	(0.98)	(0.99)	(0.56)	(1.83)	(1.96)	(4.87)	(2.29)	(1.96)
Post	-0.436	1.061	2.158	-1.117	-1.284	-0.606	0.778	0.600	0.577
	(-0.74)	(1.58)	(2.64)	(-1.85)	(-1.90)	(-0.73)	(1.27)	(0.91)	(0.74)
ANN*Post	-3.115	-2.975	-2.722	0.017	2.976	1.504	8.376	3.064	3.806
	(-1.05)	(-0.88)	(-0.67)	(0.01)	(0.88)	(0.36)	(2.72)	(0.93)	(0.97)
SUR*Post	5.485	-2.573	1.047	1.871	-0.190	1.214	5.928	-12.355	-8.578
	(0.70)	(-0.29)	(0.10)	(0.23)	(-0.02)	(0.11)	(0.72)	(-1.41)	(-0.82)
(ANN+SUR)*Post	5.049	-1.512	3.205	0.754	-1.474	0.608	6.706	-11.755	-8.000
p-value	0.7468	0.5067	0.8688	0.8012	0.7399	0.7910	0.0609	0.2569	0.6233

Table 10 (continued):

Period	[-30,-20]			[-20,-10]			[-10,0]		
Model	1	2	3	4	5	6	7	8	9
Dependent	Ret	OIN	OID	Ret	OIN	OID	Ret	OIN	OID

Panel C: E-mini Nasdaq 100 futures

Intercept	-0.581	-0.047	-0.307	0.216	-0.032	-0.388	-1.479	-0.572	-0.760
	(-0.89)	(-0.10)	(-0.51)	(0.33)	(-0.07)	(-0.69)	(-2.12)	(-1.32)	(-1.38)
ANN	-0.975	5.895	5.451	2.019	3.236	3.272	-9.695	1.342	-1.534
	(-0.28)	(2.30)	(1.67)	(0.58)	(1.35)	(1.07)	(-2.58)	(0.57)	(-0.52)
SUR	3.223	-2.391	4.466	5.029	1.944	5.733	21.263	2.551	6.256
	(0.52)	(-0.53)	(0.78)	(0.82)	(0.46)	(1.07)	(3.23)	(0.62)	(1.21)
ANN+SUR	2.248	3.504	9.917	7.048	5.180	9.005	11.569	3.894	4.722
p-value	0.6618	0.3500	0.0381	0.1661	0.1380	0.0434	0.0352	0.2545	0.2754

Panel D: SPDR S&P 500 ETF

Intercept	-0.413	2.036	-0.536	-0.154	1.487	-0.063	-0.479	1.050	-0.979
	(-1.19)	(3.45)	(-0.54)	(-0.45)	(2.53)	(-0.07)	(-1.32)	(1.87)	(-1.02)
ANN	2.565	-1.522	-0.021	0.941	2.477	9.595	-5.811	4.998	9.842
	(1.41)	(-0.49)	(-0.00)	(0.52)	(0.80)	(1.90)	(-3.04)	(1.68)	(1.94)
SUR	1.050	2.619	-10.734	0.433	1.964	-11.187	19.006	11.845	11.846
	(0.31)	(0.45)	(-1.09)	(0.13)	(0.34)	(-1.18)	(5.28)	(2.12)	(1.24)
ANN+SUR	3.616	1.096	-10.755	1.375	4.441	-1.592	13.195	16.843	21.688
p-value	0.2197	0.8274	0.2025	0.6384	0.3760	0.8453	<.0001	0.0005	0.0081

Panel E: PowerShares QQQ ETF (tracking Nasdaq 100)

Intercept	-0.750	-0.557	-0.619	0.235	0.011	-0.348	-1.406	-0.985	-1.005
	(-1.20)	(-0.87)	(-0.75)	(0.37)	(0.02)	(-0.43)	(-2.01)	(-1.60)	(-1.25)
ANN	-0.408	0.618	-0.017	1.343	4.365	-5.229	-10.428	-2.420	-2.602
	(-0.12)	(0.18)	(-0.00)	(0.39)	(1.27)	(-1.21)	(-2.76)	(-0.73)	(-0.60)
SUR	2.125	4.511	13.826	7.064	1.325	5.722	23.081	11.168	13.517
	(0.35)	(0.73)	(1.74)	(1.14)	(0.22)	(0.74)	(3.44)	(1.89)	(1.75)
ANN+SUR	1.717	5.129	13.809	8.407	5.690	0.492	12.653	8.748	10.915
p-value	0.7339	0.3213	0.0390	0.1052	0.2651	0.9392	0.0247	0.0771	0.0916

Table 11: Market activities before positive and negative surprises

This table presents OLS regression results for FOMC announcements with positive and negative surprises. The dependent variables are the returns and order imbalances calculated using both number of trades and dollar volume in three event windows: [-60,-30], [-30,0], and [0,60]. We divide the surprise announcements into positive and negative surprises. Bad equals one when the announced Federal funds target rate is above the futures-implied rate by at least 12.5 bp and zero otherwise. Good equals one when the announced Federal funds target rate is below the futures-implied rate by at least 12.5 bp and zero otherwise. Panels A, B, C, D report the results on the E-mini S&P 500 futures, E-mini Nasdaq 100 futures, SPDR S&P 500 ETF, and PowerShares QQQ ETF, respectively. Corresponding t-statistics are reported in parentheses.

Period	[-30,-20]			[-20,-10]			[-10,0]		
Model	1	2	3	4	5	6	7	8	9
Dependent	Ret	OIN	OID	Ret	OIN	OID	Ret	OIN	OID
Panel A: E-mini S&P 500 futures									
Intercept	0.711	0.059	-0.363	-1.067	-0.567	-0.621	1.422	-0.115	-0.084
	(1.43)	(0.25)	(-1.25)	(-2.15)	(-2.80)	(-2.39)	(1.55)	(-0.89)	(-0.46)
ANN	0.096	-0.742	1.041	-3.318	0.066	0.413	7.041	-0.506	0.008
	(0.04)	(-0.63)	(0.71)	(-1.34)	(0.07)	(0.32)	(1.53)	(-0.78)	(0.01)
Bad	-2.936	1.348	3.102	-16.345	-0.007	2.090	-31.876	-0.384	-2.893
	(-0.28)	(0.27)	(0.51)	(-1.58)	(-0.00)	(0.39)	(-1.67)	(-0.14)	(-0.76)
Good	-1.842	-0.147	-5.397	19.059	10.752	12.997	-9.093	-0.108	-0.775
	(-0.30)	(-0.05)	(-1.50)	(3.10)	(4.29)	(4.04)	(-0.80)	(-0.07)	(-0.34)
Panel B: E-mini Nasdaq 100 futures									
Intercept	0.977	-0.090	0.013	-1.938	-0.170	-0.286	1.943	0.215	0.165
	(1.05)	(-0.41)	(0.05)	(-2.38)	(-0.89)	(-1.09)	(1.33)	(1.67)	(0.89)
ANN	1.311	-1.045	-0.050	-5.306	1.111	0.094	8.857	-0.548	0.269
	(0.28)	(-0.94)	(-0.03)	(-1.28)	(1.15)	(0.07)	(1.20)	(-0.84)	(0.28)
Bad	-9.422	-4.068	-3.702	-25.351	-5.634	-6.804	-122.704	-1.026	-4.152
	(-0.52)	(-0.95)	(-0.64)	(-1.59)	(-1.51)	(-1.32)	(-4.29)	(-0.41)	(-1.14)
Good	-1.450	1.623	-2.820	24.212	2.555	8.208	2.564	1.286	-0.044
	(-0.13)	(0.62)	(-0.79)	(2.47)	(1.11)	(2.60)	(0.15)	(0.84)	(-0.02)

Table 11 (continued):

Period		[-30,-20]			[-20,-10]			[-10,0]	
Model	1	2	3	4	5	6	7	8	9
Dependent	Ret	OIN	OID	Ret	OIN	OID	Ret	OIN	OID
Panel C: SPDR S&P 500 ETF									
Intercept	0.312	1.646	-0.086	-1.027	0.975	-0.180	1.587	1.368	-0.209
	(0.58)	(5.41)	(-0.15)	(-1.91)	(3.39)	(-0.34)	(1.72)	(5.95)	(-0.53)
ANN	-0.036	0.855	5.212	-2.562	1.488	4.954	6.805	-1.152	-1.463
	(-0.01)	(0.56)	(1.83)	(-0.94)	(1.02)	(1.84)	(1.46)	(-0.99)	(-0.73)
Bad	-2.537	5.427	-21.704	-20.351	-1.360	-22.821	-29.376	-3.901	-6.923
	(-0.22)	(0.85)	(-1.84)	(-1.81)	(-0.23)	(-2.05)	(-1.53)	(-0.81)	(-0.84)
Good	-4.699	-2.936	-5.254	23.100	12.247	-5.231	-9.847	0.268	-1.323
	(-0.70)	(-0.78)	(-0.75)	(3.45)	(3.42)	(-0.79)	(-0.86)	(0.09)	(-0.27)
Panel D: PowerShares QQQ ETF (tracking Nasdaq 100)									
Intercept	1.169	0.289	-0.366	-1.703	-0.010	0.048	1.934	-0.096	-0.718
	(1.22)	(0.84)	(-0.75)	(-2.09)	(-0.03)	(0.10)	(1.36)	(-0.38)	(-1.94)
ANN	2.024	1.237	3.151	-6.271	-0.060	-3.310	8.462	-0.613	0.012
	(0.42)	(0.71)	(1.27)	(-1.51)	(-0.04)	(-1.40)	(1.17)	(-0.47)	(0.01)
Bad	-11.134	3.805	-0.207	-21.873	-0.488	-0.423	-125.550	-3.950	-1.026
	(-0.59)	(0.56)	(-0.02)	(-1.35)	(-0.08)	(-0.05)	(-4.43)	(-0.78)	(-0.14)
Good	-3.727	3.278	-3.541	28.243	9.939	11.231	1.161	5.025	5.331
	(-0.32)	(0.79)	(-0.60)	(2.85)	(2.53)	(1.98)	(0.07)	(1.61)	(1.18)