High-Frequency Measures of Informed Trading and
Corporate Announcements

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ABSTRACT

We study informed trading around announcements of merger bids (M&AD) and quarterly earnings (EAD). Extending the EKOP (1996) approach, we compute the daily posterior probabilities of informed trading on good and bad news. We find evidence of informed trading before and after M&AD and EAD. A significant part of the merger bid premium is impounded in stock prices prior to the announcement by informed buying. Post-M&AD informed trading predicts subsequent stock returns and the probabilities that the bid will be withdrawn or met with a competing bid. Pre-EAD informed trading also attenuates the price response to the announcement, and post-EAD informed trading predicts subsequent stock returns.

JEL Classification: G12

Keywords: High-Frequency Measures of Informed Trading; Daily Posterior Probabilities of Informed Trading; Good- and Bad-News Components; Lee-Ready Algorithm; Holden-Jacobsen Algorithm; M&As; Earnings Announcements; CAR; SUE
1. Introduction

How security prices incorporate the information of privately informed traders is important and has been studied extensively in theoretical papers by Grossman (1976), Grossman and Stiglitz (1980), Kyle (1985), Easley and O'Hara (1987), and many subsequent papers. While the analytical literature on this subject is well-established, obtaining empirical evidence on informed trading is challenging, because of the difficulty of determining whether trades emanate from private information. In this paper, we study the behavior of informed trading around the announcements of both corporate merger bids and corporate earnings by calculating the posterior probability of informed trading in a stock for each day, given the observed buy and sell transactions for that day. Our analysis is based on PIN, the probability of informed trading that is derived from a model developed by Easley, Kiefer, O'Hara, and Paperman (EKOP) (1996). This model allows researchers to estimate the probability of informed trading in a security from information on buy and sell transactions, and many studies of asset pricing and information asymmetry in financial markets have used estimates of PIN from this model.

However, these studies have relied almost exclusively on unconditional estimates of PIN that are based on transaction data over multi-day windows. The long estimation windows limit the precision and reliability of the conclusions that can be drawn from the studies, particularly when the focus is on trading around corporate announcements, since informed trading, if it takes place, is likely to be concentrated on only a few days around the announcement. Therefore, rather than relying on estimates of PIN, the unconditional probability of informed trading, we calculate for each day the posterior (or conditional) probability that informed trading has taken place on that day, given the number of buy and sell transactions that have been executed. For the prior (or unconditional) probability, we use estimates of PIN parameters that are constructed from earlier months. We calculate separate estimates of the probabilities of informed trading on good news, ‘informed buying’, and informed trading on bad news, ‘informed selling’. This allows us to relate our estimates of the probabilities of informed buying or informed selling to future corporate events.

When we examine the behavior of the probabilities of informed trading around merger bid announcements, we find contrasting patterns for bidder and target firms. On days prior to the
announcement there is no evidence of an increased probability of informed buying of stock in bidder firms, while there is a big increase in the probability of informed buying of the stock in target firms starting 25 trading days prior to the announcement. On the announcement day itself, the average probability of informed buying of stock in bidding firms jumps by around 12% and remains elevated for the following 10 trading days; the average probability of informed selling of bidders’ stock is essentially unchanged around the announcement. For target firms, the average probability of informed buying reaches a peak on the day prior to the announcement and then declines over the next five days. For these firms, the average probability of informed selling jumps by 37% on the announcement day, and further 10% on the following day, before declining rapidly over the next 14 trading days. Thus, there is evidence of informed buying of target firms prior to the announcement and no evidence of informed selling; after the announcement the probability of informed buying declines sharply and even falls below normal levels, while the probability of informed selling is abnormally high on the days immediately after the event. For acquiring firms, the only evidence of informed trading is an elevated probability of informed buying after the announcement.

Evidence that the informed trading prior to the merger announcement is based on information about the forthcoming announcement is provided by the finding that the probability of informed buying of the target over the 20 trading days prior to the announcement significantly reduces the announcement return: this is consistent with the merger news becoming impounded in the stock price by informed trading before the public news announcement. On the other hand, the probability of informed selling prior to the announcement does not have a significant effect on the announcement return.

The finding of increased probabilities of informed trading after merger announcements for both bidders and targets is at first surprising since it is natural to think of informed trading around a public news announcement as being based simply on private information about the announcement. While this may account for informed buying prior to the announcement, it cannot account for informed trading after the announcement. Aktas et al. (2007), who rely on a coarser measure of informed trading, also find evidence that \textit{PIN} is higher after merger announcements than before and conclude from this that the \textit{PIN} measure is defective. However, informed trading can take place after a public announcement if the valuation implications of the
information are not immediately obvious but must be inferred, and some investors are faster or better at this than others. Indeed, the analyses of Kim and Verrecchia (1994), Morris (1994), and Biais and Bossaerts (1998)¹ all indicate that informed speculation will take place after a public announcement if investors do not share common priors.

In our context, greater familiarity with competitive conditions within an industry may permit some investors to make better and faster assessments of the intensity of competition among potential rival bidders and the possibility of regulatory intervention or other factors that may lead to a bid withdrawal following an initial bid announcement. Consistent with this conjecture that the informed trading after a bid announcement reflects better information about the value implications of the bid, we find that for target firms that receive 100%-cash bids, our informed-trading measures averaged over days in the post-bid period predict both the probability that a bid will be withdrawn and that it will be met with a competing bid(s).

Our probability measures also predict the return to target shareholders in the post-bid period. The relation between informed trading and subsequent returns is strongest for 100%-cash bids because, for the target firms of these bids, informed trading depends only on information about the value of the target firms, while for bids that propose a share exchange, informed trading is likely to depend on information about the relative values of the target and the bidder as well as the probability of bid success. Trading in target and bidder firms to arbitrage the differences between their prices and the bid terms is referred to as merger arbitrage. We find evidence consistent with merger arbitrage trading in target firms that receive 100%-stock bids: for these bids, the probability of informed buying of the target firm after the bid announcement has predictive power for the relative returns on target and bidder shares. Thus we have strong evidence that the post-bid informed trading that we observe really is informed, and the evidence of post-bid informed trading that we find confirms the validity of the PIN-based statistics as measures of informed trading, rather than signifying a defect in the measure as Aktas et al. (2007) conclude.

The probabilities of informed trading around quarterly earnings announcement dates also

¹Bond and Eraslan (2010) indicate that informational differences can lead to trade if an asset’s owner makes decisions that affect that asset’s value. Information revealed through trade is then socially valuable, which increases the gains from trade and allows trading to take place.
show patterns that are consistent with what we observe for merger bid announcements, but
with significant differences. First, for the average firm there is little evidence of abnormal
informed trading until the day before the announcement, when the abnormal probability of
informed buying rises by about 6% and the probability of informed selling rises by about 3%.
When we form 10 portfolios on the basis of the earnings surprise as measured by the cumula-
tive abnormal returns around the earnings announcement, we find no significant differences in
the average probabilities of informed buying or informed selling in a 5-day pre-announcement
window. We conjecture that this is because the announcement return itself is attenuated by
pre-announcement informed trading as we find for mergers. The conjecture is confirmed when
we form portfolios on the standardized unexpected earnings, which is not affected by pre-
announcement trading. There are now highly significant differences between the portfolios in
the average probabilities of informed buying and informed selling in the 5-day pre-announcement
window. The portfolio of stocks with the highest earnings surprises has an average daily prob-
ability of informed buying that is 4.4% higher than the portfolio of stocks with the lowest
earnings surprises, and an average daily probability of informed selling that is 6.7% lower.

Similarly, the fraction of firms for which the probability of informed buying exceeds 0.9 in
the pre-announcement window is about 25% higher in the high earnings surprise decile than in
the low surprise decile, while the fraction of firms for which the probability of informed selling
exceeds 0.9 in the pre-announcement window is about twice as high for the low earnings surprise
decile as for the high surprise decile. Thus informed trading in the pre-event period is influenced
by information about the forthcoming earnings announcement. The higher probabilities of
informed trading in the pre-announcement window contrast with the findings of Benos and
Jochec (2007) and Back, Crotty, and Li (2015), who are unable to detect increases in the
probability of informed trading in this period using an unconditional version of PIN.

Given this evidence of informed trading before earnings announcements, we also test whether
higher probabilities of pre-announcement informed trading are associated with smaller price
reactions to the earnings surprise. We find that they are. This is consistent with our finding for
price reactions to merger bid announcements and is further evidence that informed trading prior
to corporate announcements has the effect of impounding part of the announcement information
in the stock price prior to the announcement.
As with merger announcements, we find strong evidence of informed trading after earnings announcements. While we do not have evidence as we did for merger bids that post-announcement informed trading predicts future events, we do find that the probabilities of informed buying and selling after the announcement have predictive power for returns over the next 13 trading days. This is consistent with the findings of Krinski and Lee (1996) who report an increase in the adverse-selection component of the bid-ask spread following earnings announcements, and of Green (2004) who finds a similar but more short-lived phenomenon in government bond markets following macro-economic announcements.

Our findings have contrasting implications for the PIN model. On the one hand, we provide robust evidence that empirical measures of the probability of informed trading derived from the model have predictive power both for subsequent merger-related events and for the stock price response to subsequent announcements of earnings and merger bids. On the other hand, we also find that these empirical measures of informed trading have predictive power for returns in both the post-earnings-announcement period and the post-merger-bid period. While this predictive power is consistent with the measures capturing informed trading, it is not consistent with the assumption of the PIN model that the market maker sets prices to reflect information in the past order flow or, more generally, with market efficiency. However, a closer look at the PIN-model structure reveals that the assumption about market-maker behavior and market efficiency is not crucial to the derivation of the empirical measures of informed trading. All that is required for this is that informed traders buy (or sell) when there is a discrepancy between the value of the security conditional on their information and the market price.

The paper is organized as follows. Section 2 presents a literature survey. In Section 3, we develop the daily posterior probabilities of informed trading. Data, classification algorithms, estimation procedure, and descriptive statistics of the probabilities are discussed in Section 4. Section 5 investigates the behavior of the daily measures around M&A announcements, the relation between pre-event informed trading and announcement returns, and the predictability of the daily measures about the post-event returns, the M&A bid outcomes, and the emergence of competing bids. In Section 6, we use earnings announcement data to corroborate the validity of the daily probability measures, formally testing the attenuation hypothesis. Section 7 concludes.
2. Related Literature

There exists an extensive prior literature on PIN, which reaches mixed conclusions about whether empirical estimates of PIN capture the probability or intensity of informed trading. Benos and Jochec (2007) and Aktas et al. (2007) fail to detect an increase in the probability of informed trading around earnings or merger announcements using an unconditional version of PIN that does not distinguish between informed buying and informed selling. Collin-Dufresne and Fos (2015) report that their estimates of PIN are actually lower in the 60 days preceding a 13D filing when an acquiring entity reports that it has reached the 5% ownership threshold than in the previous year, and argue that this “constitutes a major challenge to the argument that these liquidity measures detect informed trades.”

On the other hand, there is evidence consistent with the role of PIN as a measure of informed trading. Thus, Vega (2006) shows that firms with higher values of PIN during a quarter have less price drift following the subsequent earnings announcement; this is consistent with informed trading prior to the announcement accelerating the adjustment of the price to the information contained in the announcement. More indirect evidence that PIN may be associated with informed trading is provided in several studies. Ellul and Pagano (2006) establish a relation between IPO underpricing and the after-market PIN; Chen, Goldstein, and Jiang (2007) show that the sensitivity of firm investment to the stock price is related to their estimates of PIN; and Ellul and Panayides (2013) show that their estimates of PIN are affected by analyst following. More recently, Brennan, Huh, and Subrahmanyam (2016) estimate PIN and its components, the (unconditional) probabilities of informed buying and selling, and show that even these unconditional statistics estimated quarterly can identify informed trading around earnings announcements once account is taken of the direction of informed trading.

Duarte and Young (2009) use a more elaborate model of trading to decompose PIN into two components: one that is related to ‘pure’ informed trading (AdjPIN) and the other related to liquidity shocks (PSOS). Their asset-pricing tests find that only PSOS is priced, from which they conclude that PIN does not measure informed trading and that it is PSOS, a measure of illiquidity that is unrelated to information asymmetry, that drives the relation between PIN and the cross-section of stock returns. On the other hand, Brennan, Huh, and Subrahmanyam
Engle et al. (2008) also estimate the probability of informed trading on a daily basis and, like us, study the behavior of the daily probability around earnings announcements. They find that the proportion of informed trades increases as the announcement date approaches and declines afterwards. While they estimate an *ex-ante* measure of the probability by embedding the basic EKOP (1996) model in a setting that allows for time-varying arrival rates of informed traders and noise traders, we maintain the simpler setting of the original EKOP (1996) model and focus on the *posterior* probabilities of informed trading each day, which depend on the number of buy and sell transactions on that day. Secondly, they calculate only the probability of informed trading in general, while we distinguish between informed buying and informed selling. Most importantly, the additional complexity of their model forces them to restrict their analysis to a sample of only 16 stocks, while our sample contains more than 2,700 stocks.

Aktas et al. (2007) aim to provide a test of the validity of *PIN* as an informed-trading measure by analyzing its behavior around announcements of mergers and acquisitions where, they argue, there is extensive evidence of informed (insider) trading prior to the merger announcement. They find that their estimates of *PIN* decrease in the pre-announcement period and increase after the announcement. From this they conclude that *PIN* is a defective measure of informed trading, since they expect informed trading to be confined to the pre-announcement period. However, we shall see that informed trading in target firms does occur after the bid announcement, as some traders take advantage of their superior ability to analyze the implications of the bid either for the value of the target firm or for the relative values of the bidder and the target. Indeed we often find that the probability of informed trading is higher in the days immediately following the announcement than in the pre-announcement period. Thus, the increase in the Aktas et al. (2007) estimates of *PIN* in the post-announcement period is evidence, not of a defect in the *PIN* measure itself as they conclude, but of the greater importance of informed trading on public information in the post-announcement period, relative to informed trading on private information in the pre-announcement period.

In a recent and important paper, Baruch, Panayides, and Venkataraman (2016) use order
placement data that are available from the Euronext-Paris Exchange for 2003 to identify informed trading before unscheduled corporate events, which they operationalize as the difference between order placements prior to the event and order placements during a control period. They find evidence of more aggressive buy (sell) order placement strategies before good (bad) news events for stocks that are easy to sell short, but for stocks that are hard to sell short there is a decrease in the aggressiveness of sell orders prior to negative news events. Their findings are consistent with informed trading before the unscheduled corporate announcements that they examine. However, they do not examine informed trading in the post-announcement period and their sample is limited to 101 unscheduled corporate events, including M&As, SEOs, and dividend initiations/terminations for 95 stocks. In contrast, our analysis covers a comprehensive sample of merger bids and earnings announcements (for which our PIN-based measures are available), and we study informed trading both before and after the events.

3. Daily Posterior Probabilities of Informed Trading

In the EKOP (1996) model of informed trading, one of three possible events occurs each day: there is no news about the stock ($\emptyset$), there is good news ($g$), or there is bad news ($b$). The unconditional probabilities of these events are denoted by $Pr(\emptyset) = (1 - \alpha)$, $Pr(g) = \alpha(1 - \delta)$, and $Pr(b) = \alpha \delta$, respectively, where $\alpha$ is the probability that an information event occurs on the day, and $\delta$ is the probability that the event is bad news. If a news event occurs, it is observed only by a class of informed traders who trade to take advantage of it: if a good-news (bad-news) event occurs, the informed traders buy (sell) at the rate $\mu$, and, whether or not a news event occurs, noise traders buy and sell at the rates $\epsilon_B$ and $\epsilon_S$, respectively. The authors show how to estimate the model parameters from a time series of the numbers of daily buyer-initiated and seller-initiated transactions. The unconditional probability of informed trading, $PIN$, is defined as the probability that a trade is initiated by an informed trader and is given by the fraction of informed trades: $\frac{a\mu}{a\mu + a\epsilon_B + a\epsilon_S}$.

In the spirit of the EKOP (1996) model, we develop the posterior probability that a given trading day was a no-news, good-news, or bad-news day, conditional on observing the numbers of daily buyer-initiated trades ($B$) and seller-initiated trades ($S$) that day.
Using Bayes’ rule, the daily posterior probability that no information event has occurred on a given day, conditional on observing \(B\) and \(S\), can be expressed as:

\[
Pr(\emptyset | B, S) = \frac{Pr(B, S | \emptyset)Pr(\emptyset)}{Pr(B, S | \emptyset)Pr(\emptyset) + Pr(B, S | g)Pr(g) + Pr(B, S | b)Pr(b)}
\]  

(1)

Similar expressions can be derived for \(Pr(g | B, S)\) and \(Pr(b | B, S)\), the posterior probabilities that good-news and bad-news events have occurred.

Given the five parameters of the trading model, \(\alpha, \delta, \mu, \epsilon_B, \text{ and } \epsilon_S\), it follows from the analysis of Easley et al. (1996)\(^2\) that these posterior probabilities are given by:

\[
\pi(\emptyset | B, S) \equiv Pr(\emptyset | B, S) = \frac{(\alpha - 1)e^\mu \epsilon_B^B \epsilon_S^S}{\alpha(\delta - 1)\epsilon_S^S(\epsilon_B + \mu)^B - \epsilon_B^B[\alpha\delta(\epsilon_S + \mu)^S + (1 - \alpha)e^\mu \epsilon_S^S]}
\]  

(2)

\[
\pi(g | B, S) \equiv Pr(g | B, S) = \frac{\alpha(\delta - 1)\epsilon_S^S(\epsilon_B + \mu)^B}{\alpha(\delta - 1)\epsilon_S^S(\epsilon_B + \mu)^B - \epsilon_B^B[\alpha\delta(\epsilon_S + \mu)^S + (1 - \alpha)e^\mu \epsilon_S^S]}
\]  

(3)

\[
\pi(b | B, S) \equiv Pr(b | B, S) = \frac{\alpha\delta \epsilon_B^B(\epsilon_S + \mu)^S}{\epsilon_B^B[\alpha\delta(\epsilon_S + \mu)^S + (1 - \alpha)e^\mu \epsilon_S^S] - \alpha(\delta - 1)\epsilon_S^S(\epsilon_B + \mu)^B}.
\]  

(4)

For simplicity, we shall denote these posterior probabilities calculated each day by \(\pi_\emptyset, \pi_g, \text{ and } \pi_b\), respectively. Then, the posterior probability, conditional on observing \(B\) and \(S\), that an information event has occurred on a given day is defined by \(\pi_e = (1 - \pi_\emptyset)\).

4. Data and Estimation of Model Parameters and Daily Posterior Probabilities

4.1. Data, Classification Algorithms, and Estimation

As a first step in estimating the daily posterior probabilities of informed trading, we process order flows using trades and quotes available from the Institute for the Study of Security Markets (ISSM) and the NYSE Trades and Automated Quotations (TAQ) databases. For the 1983-2006 period, the Lee and Ready (1991) algorithm is used to match trades with quotes and to classify each trade into a buyer- or seller-initiated category. We apply the five-second delay rule to match trades with quotes from January 1983 to December 1998. Given the shorter reporting

\(^2\)We set at \(T = 1\) in Equations (12)-(14) of Easley et al. (1996).
lag between trades and quotes in later years, we use the two-second delay rule for the 1999-2006 period. Some issues related to applying the Lee-Ready method to the ‘monthly’ TAQ (as opposed to the ‘daily’ TAQ) have been raised by microstructure researchers. Considering that we lag quotes when matching them with trades and use dollar-volume-based order flows, the issue of misclassifications is not likely to be serious for the 1983-2006 period, in which high-frequency-trading volume is relatively low.

We note, however, that the past decade has witnessed significant changes in regulation, market structure, trading technologies, and trading behavior of market participants. Stoll (2014), for example, documents that since the mid-2000s the number of trades per day has increased substantially while trade size has decreased, reflecting the increasing prevalence of high-frequency trading (HFT) in recent years, especially since 2007. According to Arnuk and Saluzzi (2012), the introduction of the NBBO concept and Regulation NMS has made speed of execution paramount in the U.S. stock market, triggering a surge of HFT. Easley, Lopez de Prado, and O’Hara (2012) and Holden and Jacobsen (2014) suggest that applying the Lee-Ready (1991) method to the monthly TAQ database, which is time-stamped only to the second (as opposed to the millisecond), could induce substantial trade classification errors due to large HFT volume in recent years.

To alleviate the missclassification problem, Holden and Jacobsen (2014) propose a low-cost alternative, which is applicable to the monthly TAQ database, and show that their algorithm provides more accurate classifications than the Lee-Ready (1991) method. Therefore, we employ the Holden-Jacobsen algorithm for the last seven years in our sample (2007-2013). After matching trades and quotes based on either of the two algorithms, if a trade occurs above (below) the quote midpoint, it is considered buyer-initiated (seller-initiated). To minimize classification errors, we exclude trades executed at the quote midpoints (Sadka, 2006), which account for 5.79% of the trades in 2007.

We limit our attention to NYSE/AMEX-listed stocks because transaction-level data for

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3The main points of the Holden-Jacobsen (2014) algorithm are: (i) adjustments for withdrawn quotes, (ii) time-interpolation during each one-second period, (iii) matching trades with national best bid and offer (NBBO) quotes across different exchanges, and (iv) excluding crossed or locked NBBOs. So the time delay between quotes and trades is minimal (milliseconds at most). In addition, the number of trades in order flows processed by this algorithm increases substantially, compared to that processed by the Lee-Ready (1991) method.
NASDAQ stocks are not available to us and the NASDAQ market has different trading protocols (Atkins and Dyl, 1997). Trades and quotes in the ISSM/TAQ databases that are out of sequence, recorded before the open or after the close, or involved in errors or corrections are excluded. For the HFT sample period (2007-2013), to reduce the overflow problem when estimating the model parameters and the posterior probabilities, we count daily buy and sell trades executed in the NYSE/AMEX only, excluding trades executed at other exchanges, after processing order flows via the Holden-Jacobsen (2014) algorithm. The five PIN-model parameters, $\alpha$, $\delta$, $\mu$, $\epsilon_B$, and $\epsilon_S$, are estimated at a monthly frequency using a three-month rolling window. The monthly estimation allows us to calculate the parameters that incorporate the time-varying features of information events in a firm and trading activities based on those events.

Given the monthly estimates of the five parameters, $\alpha$, $\delta$, $\mu$, $\epsilon_B$, and $\epsilon_S$, the daily posterior probability estimates, $\pi_0$, $\pi_g$, and $\pi_b$, are then calculated from the numbers of buys ($B$) and sells ($S$) each day in the following month, using Equations (2)-(4). The procedure is repeated for the 369 months and 7,626 trading days from April 1983 to December 2013.

Panel A of Table 1 reports descriptive statistics on the daily posterior probability estimates, which are defined as follows:

$\pi_0 \equiv \pi(0|B, S)$: The posterior probability conditional on observing the number of daily buyer-initiated trades ($B$) and seller-initiated trades ($S$) that an information event did not occur on a given day, as defined in Equation (2).

$\pi_g \equiv \pi(g|B, S)$: The posterior probability that a good-news event occurred on a given day conditional on observing $B$ and $S$, as shown in Equation (3).

$\pi_b \equiv \pi(b|B, S)$: The posterior probability that a bad-news event occurred on a given day conditional on observing $B$ and $S$, as shown in Equation (4).

For comparison purposes, the monthly estimates of the unconditional probabilities corresponding to the three conditional probabilities described above are reported in Panel B of Table 1.

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*Note that a stock of a firm listed on the NYSE/AMEX can be executed at other exchanges and the Holden-Jacobsen (2014) algorithm uses all trades including such trades.

*Since model parameters estimated over the previous three months are used to calculate the current month’s posterior probabilities of informed trading, the daily posterior probability estimates start from the second quarter of 1983. To reduce the overflow problem when computing the probabilities using Equations (2)-(4) as they are, we use the reciprocals of the equations and then transform them back to the probabilities.
1. They are defined as follows:

\(1 - \alpha\): The unconditional probability that no information event occurs on a given day.

\(\alpha(1 - \delta)\): The unconditional probability that a good-news information event occurs on a day (\(\delta\) is the probability with which the information event contains bad news).

\(\alpha\delta\): The unconditional probability that a bad-news information event occurs on a day.

It is possible that estimates of \(\alpha\), the probability that a private information event occurs, may be biased in recent years as a result of changes in order submitting practice and the disconnect between underlying orders and trades due to order splitting. For example, studies document that, owing to the development of computer technology, aggressive informed traders tend to split orders into multiple, smaller ones.\(^6\) This would leave the relative number of buys and sells the same, but the increase in the arrival rate of informed trades may possibly lead to an upward bias in estimates of \(\alpha\), which would in turn bias the estimates of the posterior probabilities of informed trading.

To investigate this issue, we compute the cross-sectional average of the five model parameters \((\alpha, \delta, \mu, \epsilon_B, \text{ and } \epsilon_S)\) each month and plot the time series of the average values in Figure 1. Figures 1(B) and 1(C) show that the estimated arrival rates, \(\mu, \epsilon_B, \text{ and } \epsilon_S\), which are related to trading frequencies, were increasing until early 2009 consistent with Vega (2006), who estimates an unconditional PIN over the 40-day period prior to the earnings announcement date for 1986-2001. By 2013, \(\epsilon_B\) and \(\epsilon_S\) have decreased to pre-crisis levels. In particular, Figure 1(B) shows that the arrival rate of informed trades, \(\mu\), has increased since the late 1990’s, and from 2007 it remains high, compared to the arrival rates of uninformed trades. Despite the high level of \(\mu\) in recent years, however, Figure 1(A) indicates that the probability that an information event occurs on a given trading day, \(\alpha\), is stationary over the sample period without any discernible structural change, which is again consistent with Vega (2006) but not with Duarte, Hu, and Young (2015).\(^7\) The probability that a news event is bad, \(\delta\), rises from around 0.4 to 0.5 around the time of the financial crisis, while \(\alpha\), the probability that a news event (of any kind) occurs, is relatively stable at around 0.3.


\(^7\)See Figure 3(a) of their paper.
4.2. Descriptive Statistics

Table 1 reports time-series averages of daily and monthly statistics of the cross-sectional distributions of the posterior (or conditional) and prior (or unconditional) probabilities of informed trading. The average number of stocks used each day (or month) is about 2,798. The averages of the posterior daily (Panel A) and unconditional monthly (Panel B) probabilities are very close, as we expect. The average posterior (unconditional) probability of no information event is $\pi_\emptyset = 67.6\%$ (cf. $(1 - \alpha) = 68.5\%$). The average posterior (unconditional) probability of informed trading on good news or ‘informed buying’ is $\pi_g = 19.0\%$ (cf. $\alpha(1 - \delta) = 18.1\%$), while the average posterior (unconditional) probability of informed trading on bad news or ‘informed selling’ is $\pi_b = 13.4\%$ (cf. $\alpha\delta = 13.4\%$). The lower probabilities of informed selling are consistent with higher costs of trading on bad information, which may involve costly short sales (e.g., see Lamont and Thaler, 2003; Ofek, Richardson, and Whitelaw, 2004). The posterior probabilities exhibit more than twice the variability across stocks on a given day as the unconditional probabilities due to the additional information contained in the numbers of buy and sell orders each day. We see that $\pi_g$, $\pi_b$, and their unconditional counterparts are positively skewed. This implies that very high probabilities of informed trading are concentrated among a few stocks; and the range of estimated probabilities is from zero to one.

Panel C reports the distributions of the $\pi_\emptyset$, $\pi_g$ and $\pi_b$ estimates. The distributions of all three probabilities are bi-modal with most of the mass concentrated below 0.1 or above 0.9. Thus, considering $\pi_\emptyset$, we see that on about 59% of firm-days the probability that no information event occurs is above 0.9, while on 26% of the days the probability that no information event occurs is less than 0.1. On the remaining 15% of the days there is more uncertainty about whether an information event occurred. On 75% (82%) of the firm-days the probability that there is informed trading on good (bad) news is below 0.1, and on 14% (10%) of the firm days the probability of informed buying (selling) is above 0.9. Thus there is a high ($> 0.9$) probability of informed trading on about 24% of the firm-days. In the following we shall refer to days on which the estimate of $\pi_g$ ($\pi_b$) is in excess of 0.9 as good-news (bad-news) days.

Table 2 reports statistics on the correlations between the probability estimates. Panel A

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8Note that $\pi_\emptyset + \pi_g + \pi_b = 1, \pi_e = 1 - \pi_\emptyset$, and $\pi_e = \pi_g + \pi_b$.13
reports the time-series averages of the daily cross-sectional correlations between the conditional probability estimates. \( \pi_g \) and the other two measures, \( \pi_g \) and \( \pi_b \), are strongly negatively correlated (−0.70 and −0.56, respectively) on average: the probability of informed buying or selling for a firm is negatively related to the probability of no-news event. The correlation between \( \pi_g \) and \( \pi_b \) is only −0.19, so that the association seems weak. Since correlations can be misleading when the data are highly non-normal as seen in Table 1, Panel B presents a contingency table showing the joint distribution of the extreme values of \( \pi_g \) and \( \pi_b \). We see that on 59.8% of the firm-day observations the probability of both good-news and bad-news informed trading is below 0.1; a further 14.6% are good-news days and 9.7% are bad-news days, leaving only about 16% of the days in which both \( \pi_g \) and \( \pi_b \) fall into the intermediate range of 0.1-0.9. Thus, while a high probability of good (bad) news implies a low probability of bad (good) news, low probabilities of good and bad news tend to occur together (on no-news days).

Panel C reports the time-series averages of the monthly cross-sectional correlations between the unconditional probability estimates. It is the unconditional probability counterpart of Panel A, and we see that the patterns of the (average) cross-sectional correlations of the monthly unconditional probability estimates are similar to those of the daily conditional probability estimates reported in Panel A.

Panel A of Figure 2 plots the time series of the monthly averages of the daily posterior probabilities, \( \pi_g \) and \( \pi_b \). While there is considerable time-series variation in the monthly average probabilities of informed trading, we find no apparent trend. In most months, \( \pi_b \) is smaller than \( \pi_g \), but during the 2007-2013 period of financial crisis, \( \pi_b \) is often much higher.

4.3. Two stocks

To illustrate the behavior of the posterior probabilities, Panel B of Figure 2 plots the daily probabilities, \( \pi_g \) (‘pi\_g’ in the legend) and \( \pi_b \) (‘pi\_b’), for two stocks, Walgreen and Xerox, for the two-year period from January 1984 to December 1985. The corresponding monthly unconditional probabilities, \( \alpha(1 - \delta) \) and \( \alpha\delta \), are also shown, with the monthly values being held constant over the days within the month. For both stocks, periods of high posterior probabilities of both informed buying and informed selling alternate with periods in which one
of the two probabilities dominates or the probability of informed trading remains close to zero for an extended period of time. Even during periods in which the probability of informed trading tends to be positive, there are many days on which the probability of informed trading is essentially zero and, consistent with the distribution of probability estimates in Table 1, when a posterior probability of informed trading is above zero, it tends to be close to unity.

For Walgreen in Panel B(a), only the posterior probability of informed buying ($\pi_g$) tends to be significant in the first quarter of 1984, since the prior (or unconditional) probability of informed selling, $\alpha \delta$, is close to zero most of the time; in the following four quarters (up to February 1985), high probabilities of informed buying and selling are common.\textsuperscript{9} In the final three quarters of the period, virtually all the probability weight is on informed buying ($\pi_g$). The trend of the corresponding monthly unconditional probability, $\alpha (1 - \delta)$, is consistent with the level of the daily conditional probability of informed buying ($\pi_g$).

Xerox in Panel B(b) has positive probabilities of informed selling ($\pi_b$) in the first month of 1984, followed by an absence of informed trading for the next three months (up to April) of 1984. Then the probability of informed buying ($\pi_g$) dominates for the remainder of 1984, reflecting the high level of the corresponding monthly unconditional probability [$\alpha (1 - \delta)$]. For the early months and the last quarter of 1985, high probabilities of informed buying and selling occur with varying intensity. During the four middle months (April to July) of 1985, we see high probabilities of informed selling ($\pi_b$). The monthly unconditional probability of informed selling ($\alpha \delta$) tends to rise from the ending month of 1984, consistent with the level of the daily conditional probability of informed selling ($\pi_b$).

5. Informed Trading around M&A Announcements

Mergers are important corporate events that have major consequences for value and control. Prior research shows that M&A announcements have significant effects on the share prices of the firms involved, especially the target firms, so that trading on private information related

\textsuperscript{9}Note that not only is it possible to have positive probabilities of informed buying and selling on the same day, but days with high probabilities of informed buying and selling can follow in quick succession as different pieces of news come to be reflected in stock prices.
to M&As can result in large profits (e.g., see Cornell and Sirri, 1992; Chakravarty and McConnell, 1999; Mulherin and Boone, 2000; Andrade, Mitchell, and Stafford, 2001; Aktas, de Bodt, and Roll, 2004). It is not surprising therefore that there is evidence of information leakage and insider trading prior to the M&A announcement date (hereafter M&AD). In a study by Meulbroek (1992), for example, most cases of insider trading detected and prosecuted by the SEC occurred before M&A announcements. Keown and Pinkerton (1981) and Meulbroek (1992) present evidence that trading on private information prior to bid announcements causes abnormal returns.

Given the pronounced price movements and trading activities around the announcement, merger bid announcements present an ideal opportunity to examine the behavior of the estimated daily probabilities of informed trading. However, as mentioned above, Aktas et al. (2007) are unable to detect any increase in a standard measure of PIN before merger announcements in a sample of 87 French M&As over the period 1995-2000. We shed more light on this issue in the discussion below.

5.1. Behavior of Returns and Daily Probabilities around the M&AD

To analyze the behavior of the estimated daily posterior probabilities of informed trading around the initial merger bid announcement dates (M&AD: day $d$), M&A data are taken from SDC Platinum for tender offers (both completed and withdrawn) in the U.S. between 1983 and 2013 that have a transaction value of at least $50$ million. After requiring that both acquiring (or bidding) and target firms be listed on the NYSE/AMEX so that the probabilities can be calculated, the final sample includes 7,172 bidder firms and 2,623 target firms. Daily stock returns and other variables are obtained from CRSP.

For each day from $d-60$ to $d+15$, we calculate cross-sectional averages of the daily abnormal stock returns and of the daily conditional probabilities of informed trading for the acquiring firms and target firms, where the abnormal return is the difference between the stock return and the S&P500 Index return. Figure 3 shows the averages of the daily abnormal returns from day $d-40$ to day $d+15$ for acquiring and target firms. In Figure 3(A), the average abnormal

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10 The graphs for raw returns are similar to those of abnormal returns.
daily stock return ($R_{abn}^{\text{abn}}$) of the bidder firms is close to zero on most days, although the return on days $d$ and $d+1$ is slightly positive.\textsuperscript{11} However, the behavior of the average abnormal return for target firms in Figure 3(B) is quite different. The return is positive from day $d-34$ and increases sharply from day $d-5$, reaching more than 1% on day $d-1$. The abnormal return is as high as 13.2% on day $d$ and about 6.7% on day $d+1$.\textsuperscript{12}

Given the average premium of 36% paid for target firms’ shares [Kengelbach and Roos (2011)] and their positive pre-announcement abnormal returns, as well as anecdotal evidence of pre-announcement insider trading, we expect to find evidence of informed buying of the target firm during the pre-announcement period.

To capture abnormal levels of informed trading around bid announcements, we calculate abnormal probabilities of trading on good and bad news, $\pi_g^{\text{abn}}$ and $\pi_b^{\text{abn}}$ respectively, where the abnormal probability is the posterior probability ($\pi_g$ or $\pi_b$) for a particular day (relative to the M&AD denoted by day $d$) minus the average of the corresponding daily probabilities over 20 pre-announcement trading days from $d-60$ to $d-41$. Figure 4 plots averages of daily abnormal posterior probabilities of informed trading around the M&AD.

Figures 4(A1) and 4(B1) show that the abnormal probability of informed trading ($\pi_g^{\text{abn}}$) is close to zero for bidder firms in the pre-M&AD period, about 14% on the M&AD, and over 18% on day $d+1$, before declining rapidly over the following few days. For target firms the probability is positive from day $d-39$. It starts to rise around day $d-10$, and is over 10% on each of the following days, reaching 18% of day $d-1$. The abnormal probability ($\pi_e^{\text{abn}}$) for target firms is over 50% on day $d$ and over 57% on day $d+1$. It does not fall below 10% until day $d+8$. This evidence is consistent with Aktas et al. (2007), who report higher values of PIN in the post-M&AD period.\textsuperscript{13}

Figures 4(A2) and 4(A3) show that most of the informed trading in bidder firms is post-M&AD informed buying ($\pi_g^{\text{abn}}$). For target firms shown in Figures 4(B2) and 4(B3), most of the

\textsuperscript{11}Kengelbach and Roos (2011) also shows that the cumulative abnormal return of acquirers over seven days ($d-3$ to $d+3$) around the M&AD in 2010 is slightly positive (see Exhibit 3 of their article).

\textsuperscript{12}For 1,990 target firms in completed M&As only (excluding withdrawn bids), the two numbers are higher: 14.3% and 7.1%, respectively.

\textsuperscript{13}But they use very long windows to estimate PIN, and ignore the 7 trading days around the announcement ‘because it was too small to infer values for the different PIN parameters.’
pre-announcement informed trading is informed buying, as one might expect. The abnormal probability of informed buying ($\pi_{g}^{abn}$) persists for four days beyond the M&AD and then turns negative. The abnormal probability of informed selling ($\pi_{b}^{abn}$) of target firms jumps from 2% on day $d-1$ to over 37% on the M&AD and 46.5% on day $d+1$, declining towards zero over the next 14 trading days.

While the informed-trading measures show that there is an abnormally high probability of informed buying ($\pi_{g}^{abn}$) of target firms on the days prior to the bid announcement, we have not established that what we have described as informed buying actually reflects information about the forthcoming bid. And the evidence of post-announcement informed trading that we have found is puzzling if informed trading is thought of as being based solely on private information. As mentioned above, however, it is possible that informed trading is based on superior ability to analyze public information.

Therefore, we shall consider first whether informed trading prior to a bid announcement impounds information about the bid in the stock price and thereby reduces the stock price reaction to the bid announcement. Then, we shall examine whether the informed trading after the bid announcement reflects information about the bid outcomes and, if so, whether this is information that is not already reflected in the stock price.

### 5.2. Pre-Announcement Informed Trading and the Announcement Return

Models of price formation in security markets imply that informed trading causes the information on which it is based to be impounded in the stock price; this informed trading hypothesis is confirmed by Meulbroek (1992), who shows that for a sample of firms in which insider trading was charged by the SEC, almost half the pre-announcement run-up in the share price occurred on days on which insiders traded. Therefore, if there is informed buying of shares in target firms prior to the bid announcement, we should expect that a significant part of the bid premium measured relative to the undisturbed stock price will be impounded in the target firm’s share price before the announcement. This implies that the announcement return will be lower when there has been more informed buying prior to the announcement.

To investigate this, we regress the M&A announcement return on the average probabilities of informed buying and informed selling computed over 20 days prior to the M&AD,
AVGπg(−20, −1) and AVGπb(−20, −1). The M&A announcement return, CAR (0, +1), is the cumulative abnormal return over the two trading days (days d and d+1) around the M&AD, where the abnormal return is the difference between the daily stock return and the S&P500 Index return. The results are reported in Table 3.

Regression (i) shows that the coefficient of AVGπg(−20, −1) is negative and highly significant so that the greater is the estimated probability of informed buying, the lower is the announcement return, as we would expect from the informed trading hypothesis if πg captures informed buying. The coefficient implies that a one-standard-deviation increase (0.219) in the average probability of informed buying reduces the announcement return by 3.64%. However, it is possible that πg has nothing to do with informed buying but is associated with positive price changes because of the way it is calculated.14 The measure of informed buying would then be associated mechanically with the pre-announcement price run-up, which could lead to a spurious relation between AVGπg(−20, −1) and the announcement return, CAR(0, +1). To allow for this possibility, regression (ii) includes the average stock return over the 20 days prior to the bid announcement, AVGR(−20, −1), as an additional regressor. The coefficient of AVGπg(−20, −1) remains highly significant and its value is little changed, while the coefficient of AVGR(−20, −1) is negative and significant. This is strong evidence that, as the informed trading hypothesis predicts, the price movement associated with pre-M&AD informed trading has an incremental effect in reducing the price reaction to the bid announcement, in addition to the effect of the pre-announcement price movement in general.

On the other hand, there is no evidence that pre-announcement informed selling, captured by AVGπb(−20, −1) in specifications (iii)-(vi), has any effect on the announcement return. This is as we should expect, since any informed selling prior to the bid will be based on information other than the likelihood of a forthcoming bid. These findings not only validate πg as a measure of informed buying, but also imply that information about tender offers leaks out prior to the announcement date (M&AD) and is partially impounded in the stock price through pre-announcement informed buying.

14Recall that the Lee-Ready (1991) and Holden-Jacobsen (2014) algorithms classify trades as buyer- or seller-initiated using the mid-point price.
5.3. Post-Announcement Informed Trading and Bid Outcomes

We have noted that the estimated probabilities of informed trading are abnormally high in the days following an initial bid, and that Aktas et al. (2007) use this finding to cast doubt on the usefulness of PIN-like measures to proxy for the existence of informed trading. They argue that this is in direct contradiction with intuition, and ask “why would a public announcement increase the level of information-based trading?” On the other hand, the models of Kim and Verrecchia (1994, 1997) and Chung et al. (2014), among others, suggest that announcements of public information may allow certain traders to make judgments about a firm’s performance that are superior to those of other traders and, as a result, to make informed trades after the release of a public information signal. As Vega (2006, p. 105) remarks, “it is possible that the private signals that agents receive are triggered by public information that is not easily interpreted (see, e.g., Kim and Verrecchia, 1994, 1997). In other words, PIN is not exclusively an insider trading measure, since it also captures informed trading by investors who are particularly skillful in analyzing public news.”

Krinski and Lee (1996) also show that the adverse-selection component of bid-ask spreads in NYSE/AMEX-listed stocks increases substantially immediately before and after earnings announcements, with the increase after the announcements being much greater. This is consistent with informed trading after the announcement. Similarly, Green (2004) finds that the public release of macro-economic news increases the level of information asymmetry in the U.S. Treasury bond market, suggesting that some market participants have an advantage in interpreting the implications of the news for equilibrium prices. Green (2004) and Vega (2006) also point out that recent studies of information-based trading in bond and currency markets are based on the hypothesis of differential ability to interpret public information.15 It is important therefore to investigate whether the estimated probabilities of informed trading in the post-announcement period truly reflect informed trading or whether they capture some other phenomenon.

A merger bid is only the first step in what can be a complex acquisition process that may not end in a completed merger. The initial bid may elicit competing bids from rivals who fear the consequences of having a large competitor, or the bid may be withdrawn by the bidder.

because of regulatory concerns, anti-trust action by the Justice Department, a change in tax regulations, market conditions that make the merger no longer attractive to the bidding firm, or defensive actions by the target firm such as a poison pill provision.\textsuperscript{16} In the first four months of 2016, for example, $400 billion worth of corporate merger offers in the U.S. were withdrawn: these included proposed mergers of Staples and Office Depot, of Halliburton and Baker Hughes, and of Pfizer and Allergan, which were withdrawn because of regulatory concerns or changes in tax rules.\textsuperscript{17} The withdrawal of a merger bid can impose significant costs on investors in the target firm, including ‘arbitrage’ investors who are trying to profit from the difference between the market price of the target and the bid price: for instance, Allergan’s stock price dropped by 20% when hopes for the merger completion were dashed by changes in tax rules. On the other hand, the emergence of competing bidders can lead to a bidding war in which the final bid price is considerably above the initial price.

Therefore, once an initial bid has been made, investors have a strong incentive to assess the likelihood of a competing bid emerging or of the initial bid being withdrawn. If some investors have a comparative advantage in making such assessments and trade on their information, this will give rise to post-announcement informed trading, which is suggested by the abnormally high estimated probabilities of informed trading that we observe after the announcement. We therefore analyze whether the probabilities of informed trading in the post-M&AD period carry information about the withdrawal of the initial bid or the appearance of other competing bid(s) after the initial bidder’s announcement.

Out of the 2,623 target firms that received initial bids between 1983 and 2013, 633 bids were withdrawn and the remaining bids (1,990) were successful. To assess whether the estimated post-announcement informed trading probabilities reflect information about possible withdrawal of the bid, we estimate probit regressions in which the dependent variable is equal to unity if the bid is withdrawn and zero otherwise. The explanatory variables are the average probabilities of informed buying and selling (and the average return) over 10 trading days (days +1 to +10) in the post-announcement period: i.e., $AVG\pi_g(+1,+10)$, $AVG\pi_b(+1,+10)$, and $AVGR(+1,+10)$. The results are reported in Table 4. Panel A includes all target firms

\textsuperscript{16}For details on reasons for M&A bidders’ withdrawals, see Table A1 in Jacobsen (2014).

\textsuperscript{17}See the New York Times, May 12, 2106.
while Panel B includes only target firms that receive 100%-cash bids; out of the 1,008 sample firms in Panel B, 289 cases were withdrawn.

Regression (i) of Panel A show that the probability of bid withdrawal is be negatively related to the post-M&AD probability of informed buying, $AVG\pi_p(+1,+10)$. This is what we should expect if the informed trading is based on information about the probability of bid success, since bid withdrawal is typically associated with a decline in the target’s share price. However, the informed buying variable becomes insignificant when $AVGR(+1,+10)$ is included in regression (ii) and the probability of informed selling is insignificant, so that these results can be regarded as only mildly supportive of the informed trading hypothesis. A possible reason for these weak findings is that the sample includes bids with stock, cash, other, or a mix of them.

For stock bids, informed trading will depend not only on the probability of bid success but also on the ratio of the prices of the target and bidder shares relative to the proposed exchange ratio, and this relative arbitrage activity may obscure the link between informed trading and bid withdrawal.

Therefore, in Panel B we restrict the sample to the target firms that receive 100%-cash bids. We still find some evidence in regression (iii) that a lower level of informed buying is associated with bid withdrawal. More importantly, now there is a very strong relation between informed selling as measured by $AVG\pi_b(+1,+10)$ and bid withdrawal in regression (iii) as well as regression (iv), which is robust to the inclusion of the return variable, $AVGR(+1,+10)$. This suggests that the high probability of informed selling that we observe over the trading days following the announcement date reflects information about the subsequent withdrawal of the bid. This is also consistent with our hypothesis that informed trading can occur in the post-bid period, because some traders are able to interpret better and more rapidly the implications of the public information that is contained in the bid announcement.

While the withdrawal of a bid has negative consequences for the shareholders of the target firm, the emergence of a competing bidder is generally positive for them, since the new bid will typically be at a higher price than the initial bid and may force the original bidder to raise its price. Therefore, we also consider whether post-announcement informed trading reflects

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18 According to the SDC Platinum database, there are three types of bids: cash, stock, and other.
information about the possible future emergence of competing bids. We use data from SDC Platinum to determine whether each initial bid is followed by one or more competing bids and estimate a probit model in which the dependent variable is equal to one if a competing bidder emerges after the initial bid and zero otherwise; the independent variables are the probabilities of informed trading after the initial bid as in the previous table. The results are reported in Table 5. Panel A includes all target firms. We find that of the total number of 2,558 initial bids, the first bidder in 334 M&A cases faces at least one competing bidder after it makes the initial bid. To avoid any confounding effect of relative-value arbitrage trading referred to above, in Panel B the sample is limited to the targets that receive 100%-cash bids; this reduces the number of observations to 964.

For both the full sample of target firms and the subsample of targets that receive cash bids, the coefficient of $AVG\pi_g(+1,+10)$ is positive and significant at the 5% level or better in all the regressions. This is strong evidence that post-announcement informed buying reflects information about the probability of a competing bid(s) emerging. The coefficient of $AVG\pi_b(+1,+10)$ is negative and significant at the 5% level for the full sample (Panel A), but is generally insignificant for the smaller sample (Panel B). Overall, our results for the emergence of new bids are also consistent with the hypothesis of post-announcement informed trading.

As a further check on the information content of our measures of post-bid informed trading, we analyze whether informed trading over the 10 trading days following the announcement predicts future returns to target shareholders, by regressing the target share return in the post-announcement period on the informed trading probabilities averaged over the 10 post-M&A trading days, $AVG\pi_g(+1,+10)$ and $AVG\pi_b(+1,+10)$, as well as the average stock return over the same period, $AVGR(+1,+10)$. The dependent variable in these regressions, $AVGR(+11,FND)$, is defined as the average of daily stock returns between day $d+11$ and the final date, FND, which is the effective date for completed M&As and the withdrawal date for withdrawn M&As.

The results are reported in Table 6. Panel A shows that, for the sample of all target firms, the informed trading probabilities have no predictive power for future stock returns. However, as mentioned above, bids that include a stock element may induce informed trading that is
motivated by differences between the relative prices of the bidder and target shares rather than by the absolute return prospects of the target. Panel B, where the sample is limited to 100%-cash bids, shows that for these bids the average probability of informed buying, \(AVG\pi_g(+1, +10)\), is strongly positively related to the subsequent return, \(AVGR(+11, FND)\). That is, more intensive informed buying in the period after the announcement predicts higher future stock returns in target firms.

We have suggested that relative-value arbitrage trading in bidder and target shares following stock-bids may obscure the relation between informed trading and future returns for the target firms. If such arbitrage trading is important, we might expect informed trading in the target shares following stock-bid announcements to predict the relative returns to bidder and target shares. To examine this possibility, we limit the sample to target firms that receive 100%-stock bids only, which reduces the number of observations substantially. We calculate the difference of daily returns between each target firm and its bidder firm \((R_{Target} - R_{Bidder})\) in the post-announcement period, and compute the average of daily return differences from day \(d+1\) (relative to the M&AD) to the final date, \(AVGDR(+11, FND)\). Then, we regress \(AVGDR(+11, FND)\) on the probabilities (and the return) averaged over the 10 days after the M&AD.

The results are reported in Table 7. To obtain the return differences, each NYSE/AMEX-listed target firm is matched with its bidder firm listed on the NYSE/AMEX, which reduces the sample size to only 228 bids. Table 7 shows that the coefficients of the informed buying variable, \(AVG\pi_g(+1, +10)\), are positive in the two regressions and statistically significant in regression (i), which does not include the average return variable. While these results lend only mild support to the hypothesis of relative-value arbitrage, we note that the sample size in these regressions is relatively small.

6. Informed Trading around Earnings Announcements

A second obvious place to look for informed trading is around quarterly earnings announcements, since earnings surprises can have significant valuation effects, which create an incentive to trade on knowledge of forthcoming announcements and lead many firms to prohibit insid-
ers from trading their shares in the pre-announcement period. Rendleman, Jones, and Latané (1982) show that positive earnings announcements are preceded by positive returns and vice versa, which suggests that informed trading prior to earnings announcements does occur. The fact that insider trading is illegal means that such traders will go to great pains to disguise their trading motives so that the detection of pre-announcement informed trading provides a strong challenge to the ability of the PIN model to detect informed trading. Moreover, as with merger bids, the interpretation of the valuation implications of an earnings announcement may require particular background knowledge and skills which will give rise to informed trading opportunities after the announcement for those endowed with the requisite knowledge and skills. Sivakumar and Waymire (1994) find that the incidence of insider trading increases significantly after the earnings announcement date (EAD) and that, like other insider trading, these trades are on average profitable and hence may be presumed to be informed.

6.1. Behavior of the Daily Probabilities around the EAD

To examine the behavior of the estimated informed trading probabilities around quarterly earnings announcements, data are taken from the CRSP/Compustat Merged (CCM) file and the IBES database. If the quarterly earnings were announced after the close (4:00 pm EST) on the IBES-reported announcement date, which is indicated by the time-stamps (but not available for the 1983-1998 sample period in IBES), the announcements are assumed to be made on the following trading day. Figure 5 shows average probabilities of good-news and bad-news informed trading for days around the announcement dates. To capture the abnormal behavior of informed trading around the announcements, we plot averages of the abnormal probabilities of informed trading on good and bad news, \( \pi_{g}^{abn} \) and \( \pi_{b}^{abn} \), respectively, where the abnormal probability is measured by the difference between the posterior probability (\( \pi_{g} \) or \( \pi_{b} \)) for a particular day (relative to the EAD denoted by day \( d \)) and the average of the corresponding daily probabilities over 30 pre-announcement trading days from \( d-40 \) to \( d-11 \). Recent studies document that as many as 43%-45% of quarterly earnings announcements are made after the close (4:00 pm to midnight).\(^{19}\) If earnings are announced after the close in the

\(^{19}\) Michaely, Rubin, and Vedrashko (2014, 2016) show that only 36%-38% of quarterly earnings announcements are made before the open (midnight to 9:30 am EST) on the EAD. The majority of announcements are made
period 1983-1998 for which time-stamp data are not available, the news will not be reflected in the stock price of the announcement date (day \( d \)), so that informed trading on this day would be based on private information.

Panel A of Figure 5 plots the average of the abnormal probabilities \( (\pi_{a}^{abn} \text{ and } \pi_{b}^{abn}) \) for all firms around the EAD. We note first that the estimated probabilities of good-news informed trading and bad-news informed trading show little evidence of a higher probability prior to day \( d-2 \). In Figures 5(A1) and 5(A2), we find that (abnormal) informed trading occurs from day \( d-2 \) and it is highest on the announcement date (day \( d \)). Given that many companies announce the earnings information during the regular trading hours, it is reasonable to expect that a significant portion of informed trading occurs before the announcement time on day \( d \).

On day \( d-1 \), the probability of informed trading rises by about 6 percentage points for good news [in Figure 5(A1)] and by about 3 percentage points for bad news [in Figure 5(A2)]. On the announcement day itself, good-news informed trading is about 17 percentage points higher than normal, and bad-news informed trading is about 9 percentage points higher. These figures compare with the average probabilities of good- and bad-news informed trading of 19% and 13% reported in Panel A of Table 1.

While we cannot tell how much of the informed trading on the EAD takes place before the announcement time (see footnote 19), the jump in the probabilities of informed trading, especially on good news on day \( d-1 \), suggests some exploitation of privileged information and that information is leaked before quarterly earnings announcements. The higher probabilities for good news than for bad news informed trading are consistent with lower costs of exploiting good news. The increased conditional probabilities of informed trading on the days prior to the announcement contrast with the finding of Benos and Jochec (2007) that the unconditional \( PIN \) tends to be lower before earnings announcements, and the finding of Back, Crottty, and Li (2015) that \( PIN \) is smaller around the announcement dates than outside announcement windows.\(^20\)

As Figures 5(A1) and 5(A2) show, the probabilities remain abnormally high but decline over

\(^{20}\)See Table 1 of their paper.
the 10 trading days following the announcement, which is consistent with the differential ability to interpret public information hypothesis discussed above. The persistence of the abnormally high probabilities is also consistent with the empirical findings of Krinski and Lee (1996) and Green (2004), which suggest that informed traders need time to assess the implications of the quarterly earnings news for future cash flows in the firm they follow.

Panel B of Figure 5 shows the average abnormal probabilities for small stocks [in Figures 5(B1) and 5(B2)] and large stocks [in Figures 5(B3) and 5(B4)] separately, where large (small) stocks are defined as those falling into the top (bottom) third of stocks by market capitalization at the month-end prior to the announcement. The average firm size for the small-sized group (MV1) is $137.6 million and for the large-sized group (MV3) is $8,915.6 million. Somewhat surprisingly, the abnormal probabilities of informed trading on good news ($\pi^{abn}_g$) are uniformly higher for large firms [Figure 5(B3) vs. Figure 5(B1)], perhaps on account of the greater liquidity in the markets for these stocks. On day $d-1$ the abnormal probability ($\pi^{abn}_g$) is around 8.4% for large firms, but only 3.5% for small firms. Figures 5(B2) and 5(B4) show that the results are similar for the abnormal probabilities of informed trading on bad news ($\pi^{abn}_b$), except that on days $d$ the abnormal probability is slightly higher for small firms.

Figure 6 shows the behavior of the abnormal probabilities for subsets of firms with the most positive (SUE10) and most negative (SUE1) standardized unexpected earnings (SUE: defined in the next subsection and Table 8). The average abnormal probability of good-news trading ($\pi^{abn}_g$) for the portfolio with the most positive earnings surprises (SUE10) starts to rise from day $d-5$ and is highest on the announcement date [see Figure 6(A)]. Similarly, Figure 6(B) shows that the average abnormal probability of bad-news trading ($\pi^{abn}_b$) for the portfolio with the most negative surprises (SUE1) increases also from day $d-5$ and is highest on the EAD.

Overall, Figures 5 and 6 provide evidence that earnings information leaks and hence trading on this information do occur one to five trading days prior to the EAD, depending on the degree of earnings surprise. In pre-announcement trading, however, the intensity of informed trading is highest on day $d-1$ (excluding informed trading made before the announcement time on day $d$).
6.2. Portfolio Analysis

The incentive to trade on private information before an earnings announcement will depend on the expected price change associated with the announcement. Other things being equal, we should expect the announcements that lead to large price changes to be preceded by higher probabilities of informed trading. To determine whether the probability of informed trading before an announcement is associated with the magnitude of the future price change, we calculate the cumulative abnormal return (\( CAR \)) for each stock around the EAD: \( CAR(0, +1) \) is the sum of the abnormal returns over the announcement day and the following day. The abnormal return for each day is the difference between the stock return and the CRSP value-weighted return from the CRSP daily file.\(^{21}\)

Each quarter for each stock, the averages of the posterior probabilities of informed trading on good news and bad news over the five trading days prior to the EAD, \( AVG\pi_{g}(-5, -1) \) and \( AVG\pi_{b}(-5, -1) \), are first calculated. Then, to form decile portfolios, the component stocks are split into ten groups (with equal number of stocks) each quarter by \( CAR \). In each portfolio in each quarter, the cross-sectional mean of the average probabilities obtained above is computed, and finally the time-series average of the quarterly cross-sectional means is reported in Table 8. Panel A shows that the mean of the cumulative abnormal announcement return \( [CAR(0, +1)] \) for the 10 portfolios ranges from -11\% to +11\%. However, the differences in the mean conditional probabilities of informed trading across the portfolios are insignificant: for example, the difference in the conditional probabilities of good-news trading over days \( d-5 \) to \( d-1 \) [i.e., \( AVG\pi_{g}(-5, -1) \)] between the most positive (CAR10) and most negative (CAR1) surprise portfolios is only 0.5\%, and the average probability of bad-news informed trading [i.e., \( AVG\pi_{b}(-5, -1) \)] is slightly higher for the CAR10 portfolio than it is for the CAR1 portfolio.

One explanation for the lack of association between the announcement returns (\( CAR \)) and the probabilities of pre-announcement informed-trading is that the announcement return depends not only on the earnings surprise itself but also on the degree to which the surprise is impounded in stock prices by informed trading prior to the announcement. Similarly to the

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\(^{21}\)The component stocks in the sample for earnings announcements are much broader in a given quarter than those for M&As, so we use the CRSP value-weighted return as the benchmark, instead of the S&P500 Index return.
M&A case, stocks with small announcement returns may be those for which the information has already been impounded in the price by pre-announcement informed trading, which would confound any relation between the announcement returns and the probabilities of pre-event informed trading.

Therefore, the analysis is repeated by replacing the indirect, return-based surprise variable (CAR) with the standardized unexpected earnings (SUE), which is a more direct measure of earnings surprises and unaffected by pre-announcement informed trading. SUE, following Livnat and Mendenhall (2006), is defined by $SUE_{it} = \frac{EPS_{it} - EPS_{it-4}}{P_{it}}$, where $EPS_{it}$ is the “street” earnings per share for firm $i$ in quarter $t$ that excludes special items from the Compustat-reported EPS [as in Abarbanell and Lehavy (2007)], $P_{it}$ is the stock price at the end of quarter $t$, and $EPS_{it-4}$ is the EPS at the end of quarter $t - 4$ (adjusted for stock splits and stock dividends). Thus, the quarterly earnings surprise is computed by assuming for forecasting purposes that EPS follows a seasonal random walk. The advantage of this SUE definition is that quarterly earning surprises can be estimated for almost all firms, unlike other SUE definitions that require analysts’ forecasts.

The results for the SUE-sorted portfolios shown in Panel B of Table 8 are quite different from the CAR-sorted portfolio results reported in Panel A. Now the difference in the average probability of pre-announcement trading on good private information [$AVG\pi_g(-5, -1)$] between the most positive (SUE10) and most negative (SUE1) surprise portfolios is 4.4% with a $t$-statistic of 10.27; this compares with the average $\pi_g$ of 19.0% shown in Panel A of Table 1. Similarly, the average probability of pre-event trading on bad private information, $AVG\pi_b(-5, -1)$, is 6.7% larger for the most negative SUE portfolio than for the most positive SUE portfolio, with its $t$-statistic on the difference being -18.71; this compares with the average $\pi_b$ of 13.4% reported in Table 1. Thus, there is strong evidence of informed trading on private information prior to earnings announcements: buying before positive earnings surprises and selling before negative earnings surprises.

This evidence is consistent with the findings of Brennan, Huh, and Subrahmanyam (2016) who show that, when PIN is estimated quarterly, its good-news component (PIN\_G) is increasing in the earnings surprise and its bad-news component (PIN\_B) is monotonically de-
creasing. However, the increased precision of the daily conditional measures of informed trading in this paper is manifest, given that our high-frequency measures incorporate the information on the number of daily buys and sells.

Further evidence of informed trading on the days prior to (and after) the announcement date is provided in Table 9, which reports the proportion of firms for which daily conditional probabilities are greater than or equal to 0.9 (i.e., \( \pi_g \geq 0.9 \) and \( \pi_b \geq 0.9 \)) around the EAD for the highest (SUE10) and lowest (SUE1) surprise portfolios. The table shows that 22.6% of firms in the SUE10 decile have a good-news day on day \( d-1 \), compared with only 16.5% of firms in SUE1. This difference extends back to day \( d-5 \), when 15.2% of firms in SUE10 have a good-news day, compared with 13.0% of the firms in SUE1. These differences are consistent with the existence of informed trading on good news up to five days before the announcement. The difference in the fractions of firms with a good-news day is very large on the announcement day itself and persists for another five trading days. For the fraction of firms with a bad-news day for the highest (SUE10) and lowest (SUE1) surprise portfolios, we find the opposite pattern: the fraction is always higher in SUE1 than in SUE10. The difference in the fractions of firms with a bad-news day is largest (by 6.5%) on day \( d-1 \) and the higher proportion in SUE1 persists around the EAD, with the difference being greater on pre-announcement days than post-announcement days. These aspects are again consistent with the existence of informed trading on bad news prior to the earnings announcement.

### 6.3. Pre-Announcement Informed Trading and the Attenuation of Announcement Returns

To explain the lack of a relation between the probabilities of pre-announcement informed trading [i.e., \( AVG\pi_i(-5,-1), i = g \) or \( b \)] and the announcement returns measured by \( CAR(0, +1) \) as in Panel A of Table 8, we have advanced the hypothesis that pre-announcement informed trading attenuates the reactions of prices (hence returns) to the announcements. Given the direct surprise (\( SUE \)) measure that is not affected by pre-event informed trading, we can formally test this hypothesis. Therefore, we estimate the following separate regressions for positive and
negative earnings surprises ($SUE$):

\[
CAR(0, +1) = a^+ + b^+ SUE + c^+ \text{AVG}\pi_g(-5, -1) + e, \text{ for } SUE > 0 \tag{5}
\]

\[
CAR(0, +1) = a^- + b^- SUE + c^- \text{AVG}\pi_b(-5, -1) + e, \text{ for } SUE < 0. \tag{6}
\]

In Equations (5) and (6), the coefficients on $SUE$, $b^+$ and $b^-$, are expected to be positive as prices respond to the earnings surprises ($SUE$). The attenuation hypothesis predicts that, to the extent that $\text{AVG}\pi_g(-5, -1)$ and $\text{AVG}\pi_b(-5, -1)$ can capture informed trading before announcements, $c^+$ is negative and $c^-$ is positive. Given that the earnings announcement event occurs repeatedly each quarter for most listed firms, we can conduct cross-sectional regressions each quarter with a much more comprehensive dataset.

Specifications (i) and (iii) in Table 10 report the results of Fama and MacBeth (1973) cross-sectional estimates of the above equations, run quarterly from the second quarter of 1983 to the fourth quarter of 2013 (123 quarters). As columns (i) and (iii) show, there are about 700 positive earnings surprises on average each quarter and only about 440 negative surprises. We find that the coefficient on $SUE$ is positive and significant for both positive and negative earnings surprises. Furthermore, the estimate of $c^+$ ($c^-$) is negative (positive) and highly significant. This is consistent with our conjecture that informed trading prior to earnings announcements does attenuate the announcement return ($CAR$). This in turn explains why the differences between the CAR1 and CAR10 portfolios for $\text{AVG}\pi_i(-5, -1)$ ($i = g$ and $b$) reported in Panel A of Table 8 are not statistically significant.

Columns (ii) and (iv) in Table 10 also report the results of regressions, in which the earnings surprise ($SUE$) is interacted with the probabilities of pre-announcement informed trading:

\[
CAR(0, +1) = a^+ + b^+ SUE + c^+ \text{AVG}\pi_g(-5, -1) + d^+ SUE^* \text{AVG}\pi_g(-5, -1) + e, \text{ for } SUE > 0 \tag{7}
\]

\[
CAR(0, +1) = a^- + b^- SUE + c^- \text{AVG}\pi_b(-5, -1) + d^- SUE^* \text{AVG}\pi_b(-5, -1) + e, \text{ for } SUE < 0 \tag{8}
\]
The two panels in Table 10 show that, consistent with the attenuation hypothesis, the estimates of $d^+$ and $d^-$ in Eqs. (7) and (8) are negative and significant for both positive and negative earnings surprises ($SUE$).

Finally, specification (v) in Panel C reports estimation of a single regression equation which combines positive and negative earnings surprises:

$$
CAR(0, +1) = a + \theta SUE + \gamma AVG\pi_i(-5, -1) + \phi SUE*AVG\pi_i(-5, -1) + \omega D_{SUE} + \epsilon,
$$

$$
i = g \text{ if } SUE > 0 \text{ and } i = b \text{ if } SUE < 0.
$$

In the above equation, $D_{SUE}$ is a dummy variable that is equal to 1 if $SUE < 0$ and 0 otherwise. Panel C shows that the coefficient ($\theta$) on $SUE$ is positive and highly significant, while the coefficient ($\phi$) on the interaction term ($SUE*AVG\pi_i$) is negative and highly significant. In all three regressions with an interaction [specifications (ii), (iv), and (v)], the coefficient on the interaction term, $SUE*AVG\pi_i(-5, -1)$, is larger by a factor of 2-3 than the coefficient on $SUE$. This implies that a daily probability of about 0.33-0.50 on the days preceding the announcement would eliminate the price response to the earnings surprise on the EAD.

The above results provide evidence in support both of the attenuation hypothesis and of the ability of the variables $\pi_g$ and $\pi_b$ to capture the intensity of informed trading. Our results confirm the findings of Vega (2006), who finds that higher values of PIN are associated with lower post-earnings-announcement drift. The main difference between her study and ours is that her independent variable is the unconditional PIN estimated using data over at least 40 trading days (only one estimate per firm) before the earnings announcement date rather than the posterior probabilities (estimated each day around the EAD) that we use, and she does not distinguish between informed trading on good news and on bad news. As a result her estimates are generally not statistically significant.

**6.4. Post-Announcement Informed Trading and Returns**

As with the merger bid analysis, our goal is to explore if the post-EAD probabilities of informed trading do in fact capture informed trading. In particular, we examine the relation between informed trading probabilities immediately after the EAD and subsequent stock returns by
estimating quarterly Fama-MacBeth (1973) regressions, in which the dependent variable is the post-announcement return over 13 trading days, \( CAR(+3, +15) \), and the explanatory variables are the probabilities averaged over two trading days (+1 and +2) immediately after the earnings announcement, \( AVG\pi_g(+1, +2) \) and \( AVG\pi_b(+1, +2) \). We include the cumulative abnormal return, \( CAR(+1, +2) \), as a control. The results are reported in Table 11.

In all specifications, the probability of informed buying, \( AVG\pi_g(0, +1) \), is positively and significantly associated with the subsequent return. The probability of informed selling, \( AVG\pi_b(0, +1) \), is also negatively associated with the subsequent return but the coefficient for this variable is smaller and less significant than for the informed buying variable. Nevertheless, the results leave no doubt that there is informed trading after earnings announcements.

7. Conclusion

Since the trades of privately informed agents help to make financial markets informationally efficient, it is important to examine empirically the activities of informed traders. A widely-used measure of informed trading is EKOP’s (1996) PIN. Most studies have so far relied on unconditional estimates of PIN that are based on transaction data over multi-day windows. But the long estimation windows limit the precision and reliability of the conclusions drawn from such studies, especially when the focus is on trading around corporate events, since informed trading is likely to be concentrated over a few days around the announcement date. In this paper, we develop daily conditional probabilities of informed trading that incorporate the information on each day’s buy and sell orders, in the spirit of the EKOP (1996) model. The conditional probabilities, which distinguish between informed buying and selling, have bimodal distributions, clustering either below 0.1 or above 0.9.

Using data on M&As, we find evidence of informed trading both before and after the bid announcement, particularly for target firms. Regression analysis reveals that a significant part of the merger premium becomes impounded in the target share price by informed buying before the bid announcement. The post-announcement probabilities of informed trading contain information about future bid withdrawals and the emergence of competing bidders, as well as
the subsequent returns to target shareholders.

Similarly, analysis of informed trading probabilities around quarterly earnings announcements yields evidence of informed trading both before and after the announcements. High probabilities of informed trading prior to the announcement reduce the stock price response to earnings surprises, confirming that the informed trading that we identify impounds information about the forthcoming earnings news into the stock price before the announcement. The informed trading probabilities after the announcement contain information about future stock returns, confirming that these probabilities are also related to informed trading.

Our results are significant, not only in establishing the ability of the PIN model to identify informed trading, but also in showing clear evidence of informed trading after public announcements, which provides support for models such as Kim and Verrecchia (1994, 1997) in which different agents have different interpretations of public information signals, or models in which different agents have different abilities to process the information in public announcements, perhaps because of different endowments of skills. The fact that we are able to identify informed trading on public information points to caution in interpreting trading on information as trading on private information.
References

Abarbanell, J., and R. Lehavy, 2007, Letting the “tail wag the dog”: the debate over GAAP versus street earnings revisited, *Contemporary Accounting Research* 24, 675-723.


Back, K., K. Crotty, and T. Li, 2015, Can information asymmetry be identified from order flows alone?, Working paper, Rice University.


**Table 1**

**Descriptive Statistics and Distributions of the Probabilities of Informed Trading for NYSE/AMEX-Listed Stocks**

This table reports descriptive statistics of posterior (or conditional) daily probabilities (in Panel A) and monthly unconditional (or prior) probabilities (in Panel B), as well as the distribution of the posterior daily probabilities for all firm-days (in Panel C). The cross-sectional value for each statistic is calculated each day (in Panel A) or each month (in Panel B) and then the time-series average of those values is reported. The variables are defined as follows. $\pi_\emptyset$: the estimated posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that no information event occurs on a given trading day; $\pi_\chi$: the estimated posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that a good-news information event occurs on a given day; and $\pi_\kappa$: the estimated posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that a bad-news information event occurs on a given day; ($1-\xi$): the monthly estimated unconditional probability that no information event occurs (hence $\xi$ is the probability with which an information event occurs) on a day; $\xi(1-\delta)$: the monthly estimated unconditional probability that a good news information event occurs on a day ($\delta$ is the probability with which the information event contains bad news); $\delta \xi$: the monthly estimated unconditional probability that a bad news information event occurs on a day. For estimating the monthly unconditional probabilities and daily conditional probabilities, each trade in the ISSM/TAQ databases is classified as buyer-initiated or seller-initiated via the Lee-Ready (1991) algorithm up to 2006 and the Holden-Jacobsen (2014) algorithm for the 2007-2013 period. The sample periods for NYSE/AMEX stocks are the past 7,626 trading days from April 1983 to December 2013 in Panel A and the past 369 months from April 1983 to December 2013. The average number of component stocks used each day (or month) is 2,798.2. The total number of firm-days used in Panel C is 20,123,969.

### Descriptive Statistics for NYSE/AMEX Stocks

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<tr>
<th>Variables</th>
<th>Mean</th>
<th>Median</th>
<th>Max</th>
<th>Min</th>
<th>STD</th>
<th>CV</th>
<th>Skewness</th>
<th>Kurtosis</th>
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<tr>
<td>$\pi_\emptyset$</td>
<td>0.676</td>
<td>0.917</td>
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<td>0.000</td>
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<td>-0.84</td>
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<td>1.000</td>
<td>0.000</td>
<td>0.300</td>
<td>244.21</td>
<td>2.38</td>
<td>4.93</td>
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</table>


<table>
<thead>
<tr>
<th>Variables</th>
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<th>Median</th>
<th>Max</th>
<th>Min</th>
<th>STD</th>
<th>CV</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>($1-\xi$)</td>
<td>0.685</td>
<td>0.696</td>
<td>1.000</td>
<td>0.001</td>
<td>0.172</td>
<td>25.17</td>
<td>-0.68</td>
<td>1.45</td>
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<td>$\xi(1-\delta)$</td>
<td>0.181</td>
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<td>0.960</td>
<td>0.000</td>
<td>0.136</td>
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<td>1.25</td>
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<tr>
<td>$\delta \xi$</td>
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<td>0.944</td>
<td>0.000</td>
<td>0.137</td>
<td>106.43</td>
<td>1.88</td>
<td>5.15</td>
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</table>


**Panel C: Distribution of the Posterior Daily Probabilities for All Firm-Days**

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<th></th>
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<th>0.10-0.20</th>
<th>0.20-0.30</th>
<th>0.30-0.40</th>
<th>0.40-0.50</th>
<th>0.50-0.60</th>
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<th>0.90-1.00</th>
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<tbody>
<tr>
<td>$\pi_\emptyset$</td>
<td>0.258</td>
<td>0.020</td>
<td>0.015</td>
<td>0.014</td>
<td>0.013</td>
<td>0.014</td>
<td>0.017</td>
<td>0.022</td>
<td>0.035</td>
<td>0.593</td>
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<tr>
<td>$\pi_\chi$</td>
<td>0.753</td>
<td>0.026</td>
<td>0.015</td>
<td>0.011</td>
<td>0.010</td>
<td>0.009</td>
<td>0.009</td>
<td>0.010</td>
<td>0.012</td>
<td>0.140</td>
</tr>
<tr>
<td>$\pi_\kappa$</td>
<td>0.821</td>
<td>0.021</td>
<td>0.012</td>
<td>0.009</td>
<td>0.008</td>
<td>0.007</td>
<td>0.007</td>
<td>0.007</td>
<td>0.010</td>
<td>0.097</td>
</tr>
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</table>
Table 2
Correlations between Daily Posterior and Monthly Unconditional (Prior) Probabilities of Informed Trading

This table reports averages of correlations between the daily posterior probabilities of informed trading as well as those between the monthly unconditional (prior) probabilities. It also reports the joint distribution of extreme values in the daily posterior probabilities of informed buying and informed selling. Panel A reports time-series averages of the daily cross-sectional correlations between the posterior probabilities. Panel B reports the joint distribution of firm-days for which the two daily posterior probabilities are both smaller than 0.1; both larger than 0.9; and one smaller than 0.1 and the other larger than 0.9. Panel C reports time-series averages of the cross-sectional correlations between the unconditional probabilities of informed trading that are estimated each month. The posterior daily probabilities are defined as follows. \( \pi_{\emptyset} \): the estimated posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that no information event occurs on a given trading day; \( \pi_{\chi} \): the estimated posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that a good-news information event occurs on a given day; and \( \pi_{\kappa} \): the estimated posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that a bad-news information event occurs on a given day. The monthly unconditional probabilities which are estimated using transaction data over the previous three months are defined as follows. \( 1 - \alpha \): the unconditional probability that no information event occurs; \( \alpha(1 - \delta) \): the unconditional probability that a good news information event occurs on a given day (\( \delta \) is the probability with which the information event contains bad news); and \( \alpha \delta \): the unconditional probability that a bad news information event occurs on a day. For estimating the monthly unconditional probabilities and daily posterior probabilities, each trade in the ISSM/TAQ databases is classified as buyer-initiated or seller-initiated via the Lee-Ready (1991) algorithm up to 2006 and the Holden-Jacobsen (2014) algorithm for the 2007-2013 period. The sample period for NYSE/AMEX stocks is the past 7,626 trading days from April 1983 to December 2013 in Panels A and B, while it is the past 369 months from April 1983 to December 2013 in Panel C. The average number of component stocks used each day or each quarter is 2,798.2. The total number of firm-days used in Panel B is 20,123,969.

| Panel A: Time-Series Average of Daily Cross-Sectional Correlations of Posterior Probabilities |
|----------------------------------|---------------------------------|-----------------|
| Measures | \( \pi_{\emptyset} \) | \( \pi_{\chi} \) | \( \pi_{\kappa} \) |
| \( \pi_{\emptyset} \) | 1 | | |
| \( \pi_{\chi} \) | -0.702 | 1 | |
| \( \pi_{\kappa} \) | -0.556 | -0.186 | 1 |

| Panel B: Joint Distribution of Extreme Values of Posterior Probabilities |
|---------------------------------|-----------------|-----------------|
| | \( \pi_{\chi} < 0.1 \) | \( \pi_{\chi} > 0.9 \) |
| \( \pi_{\kappa} < 0.1 \) | 0.598 | 0.146 |
| \( \pi_{\kappa} > 0.9 \) | 0.097 | 0.000 |

| Panel C: Time-Series Average of Cross-Sectional Correlations of Monthly Unconditional Probabilities |
|---------------------------------|-----------------|-----------------|
| Measures | \( (1 - \alpha) \) | \( \alpha(1 - \delta) \) | \( \alpha \delta \) |
| \( (1 - \alpha) \) | 1 | | |
| \( \alpha(1 - \delta) \) | -0.624 | 1 | |
| \( \alpha \delta \) | -0.623 | -0.214 | 1 |
Table 3
Informed Trading before Merger Announcements and the Announcement Return \(\{CAR(0, +1)\}\) for Target Firms
This table reports the results of regressions of the cumulative abnormal return around the M&A announcement date (M&AD: day 0) on the pre-event average daily probabilities of informed trading for NYSE/AMEX-listed target firms in completed and withdrawn M&As. The sample period is from 1983 to 2013. The dependent variable, \(CAR(0, +1)\), is the cumulative abnormal return over two trading days around the M&AD. Other variables are defined as follows. \(AVG\pi_g(\text{-}20, \text{-}1)\): the average of daily \(\pi_g\)'s from day -20 to day -1 (relative to the M&AD), where \(\pi_g\) is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that the private information is good news; and \(AVG\pi_u(\text{-}20, \text{-}1)\): the average of daily \(\pi_u\)'s from day -20 to day -1, where \(\pi_u\) is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that the private information is bad news; \(AVGR(\text{-}20, \text{-}1)\): the average of daily stock returns from day -20 to day -1. The values in the first row for each explanatory variable are the coefficients from the regressions, and the values italicized in the second row of each variable are \(t\)-statistics. \(R^2\) is the R-squared from the regressions. \(Obs\) is the number of companies used in the regressions. Coefficients significantly different from zero at the significance levels of 1%, 5%, and 10% are indicated by ***, **, and *, respectively.

| Pre-Announcement Informed Trading around M&AD and the Announcement Return for Target Firms |
|---------------------------------------------|---------------------------------------------|---------------------------------------------|---------------------------------------------|---------------------------------------------|
|                                            | Dep. Var. = \(\{CAR(0, +1)\}\)             |                                            |                                            |                                            |
|                                            | (i)                                        | (ii)                                      | (iii)                                      | (iv)                                      |
| Intercept                                  | 0.236 ***                                 | 0.238 ***                                 | 0.196 ***                                 | 0.206 ***                                 |
|                                            | 27.47                                     | 27.63                                     | 27.86                                     | 27.88                                     |
| \(AVG\pi_g(\text{-}20, \text{-}1)\)       | -0.166 ***                                | -0.150 ***                                | -0.163 ***                                | -0.145 ***                                |
|                                            | -6.50                                     | -5.71                                     | -6.48                                     | -5.60                                     |
| \(AVG\pi_u(\text{-}20, \text{-}1)\)       | -0.039                                    | -0.039                                    | -0.055                                    | -0.053                                    |
|                                            | -1.10                                     | -1.10                                     | -1.55                                     | -1.50                                     |
| \(AVGR(\text{-}20, \text{-}1)\)           | -1.638 ***                                | -2.626 ***                                | -1.779 ***                                |
|                                            | -2.59                                     | -4.29                                     | -2.83                                     |
| \(R^2\)                                    | 0.016                                     | 0.019                                     | 0.000                                     | 0.008                                     |
| \(Obs\)                                    | 2527                                      | 2527                                      | 2512                                      | 2512                                      | 2510                                      | 2510                                      |
This table reports the results of probit regressions of a bid withdrawal dummy variable on the average probabilities of informed trading on good news and bad news over the days following the initial bid announcement. The sample includes all target firms that are listed on the NYSE/AMEX over the 1983-2013 sample period. Panel A includes all target firms, while Panel B includes only target firms that receive 100%-cash payment bids. The dependent variable is equal to 1 for M&A bids that are withdrawn and 0 for M&A bids that are completed (the probit regressions are modeled for 1s). The explanatory variables are defined as follows. $AVG\pi_g(+1, +10)$: the average of daily $\pi_g$’s from day +1 to day +10 (relative to the initial M&A announcement date, M&AD), where $\pi_g$ is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that the private information is good news; $AVG\pi_b(+1, +10)$: the average of daily $\pi_b$’s from day +1 to day +10 (relative to the M&AD), where $\pi_b$ is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that the private information is bad news; and $AVG(\Delta +1, +10)$: the average of daily stock returns from day +1 to day +10 (relative to the M&AD). The values in the first row for each explanatory variable are the coefficients from the regressions, and the values italicized in the second row of each variable are $p$-values. Pseudo $R^2$ is the pseudo $R$-squared from the probit regressions. Obs is the number of target firms used in each of the regressions. Coefficients significantly different from zero at the significance levels of 1%, 5%, and 10% are indicated by ***, **, and *, respectively.

### Probit Regressions after the M&AD: Dep. Var. = 1 for Withdrawn Bids and 0 Otherwise

<table>
<thead>
<tr>
<th></th>
<th>Panel A: All M&amp;A Targets</th>
<th>Panel B: 100%-Cash M&amp;A Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(i)</td>
<td>(ii)</td>
</tr>
<tr>
<td>Intercept</td>
<td>-0.633 ***</td>
<td>-0.628 ***</td>
</tr>
<tr>
<td></td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>$AVG\pi_g (+1, +10)$</td>
<td>-0.659 *</td>
<td>-0.212</td>
</tr>
<tr>
<td></td>
<td>0.094</td>
<td>0.684</td>
</tr>
<tr>
<td>$AVG\pi_b (+1, +10)$</td>
<td>0.097</td>
<td>0.058</td>
</tr>
<tr>
<td></td>
<td>0.770</td>
<td>0.861</td>
</tr>
<tr>
<td>$AVG\Delta (+1, +10)$</td>
<td>-0.226</td>
<td>0.200</td>
</tr>
<tr>
<td>Pseudo $R^2$</td>
<td>0.002</td>
<td>0.003</td>
</tr>
<tr>
<td>Obs</td>
<td>2613</td>
<td>2613</td>
</tr>
</tbody>
</table>
Table 5
Post-Announcement Informed Trading and the Emergence of Competing Bids

This table reports the results of probit regressions of a multi-bidder dummy variable on the average probabilities of informed trading on good news and bad news over the days following the initial bid announcement. The sample includes all target firms that are listed on the NYSE/AMEX over the 1983-2013 sample period. Panel A includes all target firms, while Panel B includes only target firms that receive 100%-cash payment bids. The dependent variable is equal to 1 if a target firm faces any competing bidder(s) after the initial bidder announces its M&A intention and 0 otherwise (the probit regressions are modeled for 1s). The explanatory variables are defined as follows. \( \overline{AVGn_g}(+1, +10) \): the average of daily \( \pi_g \)'s from day +1 to day +10 relative to the initial announcement date (M&AD), where \( \pi_g \) is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that the private information is good news; \( \overline{AVGn_b}(+1, +10) \): the average of daily \( \pi_b \)'s from day +1 to day +10 relative to the M&AD, where \( \pi_b \) is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that the private information is bad news; and \( \overline{AVGr}(+1, +10) \): the average of daily stock returns from day +1 to day +10 relative to the M&AD. The values in the first row for each explanatory variable are the coefficients from the regressions, and the values italicized in the second row of each variable are \( p \)-values. Pseudo R\(^2\) is the pseudo R-squared from the probit regressions. Obs is the number of target firms used in each of the regressions. Coefficients significantly different from zero at the significance levels of 1%, 5%, and 10% are indicated by ***, **, and *, respectively.

<table>
<thead>
<tr>
<th></th>
<th>Panel A: All M&amp;A Targets</th>
<th></th>
<th>Panel B: 100%-Cash M&amp;A Targets</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(i)</td>
<td>(ii)</td>
<td></td>
<td>(iii)</td>
</tr>
<tr>
<td>Intercept</td>
<td>-1.221 ***</td>
<td>-1.213 ***</td>
<td>-1.408 ***</td>
<td>-1.397 ***</td>
</tr>
<tr>
<td></td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>( \overline{AVGn_g}(+1, +10) )</td>
<td>1.114 **</td>
<td>1.848 ***</td>
<td>1.736 **</td>
<td>3.428 ***</td>
</tr>
<tr>
<td></td>
<td>0.015</td>
<td>0.002</td>
<td>0.029</td>
<td>0.002</td>
</tr>
<tr>
<td>( \overline{AVGn_b}(+1, +10) )</td>
<td>-0.907 **</td>
<td>-0.955 **</td>
<td>0.069</td>
<td>-0.109</td>
</tr>
<tr>
<td></td>
<td>0.017</td>
<td>0.012</td>
<td>0.916</td>
<td>0.869</td>
</tr>
<tr>
<td>( \overline{AVGr}(+1, +10) )</td>
<td>-0.381 *</td>
<td></td>
<td>-0.840 **</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.071</td>
<td>0.022</td>
<td></td>
</tr>
<tr>
<td>Pseudo R(^2)</td>
<td>0.002</td>
<td>0.004</td>
<td>0.010</td>
<td>0.016</td>
</tr>
<tr>
<td>Obs</td>
<td>2558</td>
<td>2558</td>
<td>964</td>
<td>964</td>
</tr>
</tbody>
</table>
Table 6
Regressions of the Post-Announcement Return on the Probabilities of Informed Trading in the Post-Announcement Period for Target Firms

This table reports the results of regressions of the M&A post-announcement return on the average daily conditional probabilities over the days after the M&A announcement date (M&AD) for NYSE/AMEX-listed target firms. The sample period is from 1983 to 2013. Panel A includes all target firms, while Panel B includes only target firms that receive 100%-cash payment bids. The dependent variable is $AVGR(+11, FND)$, the average of daily returns from day +11 after the announcement date (M&AD+11) to the final date (FND), where FND is the effective date for completed M&As and the withdrawn date for withdrawn M&As. Other variables are defined as follows. $AVGr(\pi_g(+1, +10))$: the average of daily $\pi_g$’s from day +1 to day +10 (relative to the initial M&A announcement date, M&AD), where $\pi_g$ is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that the private information is good news; $AVGr(\pi_\alpha(+1, +10))$: the average of daily $\pi_\alpha$’s from day +1 to day +10 (relative to the final M&A announcement date, M&AD), where $\pi_\alpha$ is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that the private information is bad news; and $AVGr(+1, +10)$: the average of daily stock returns from day +1 to day +10. The values in the first row for each explanatory variable are the coefficients from the regressions, and the values italicized in the second row of each variable are t-statistics. All coefficients are multiplied by 100. $R^2$ is the R-squared from the regressions. $Obs$ is the number of target companies used in the regressions. Coefficients significantly different from zero at the significance levels of 1%, 5%, and 10% are indicated by ***, **, and *, respectively.

<table>
<thead>
<tr>
<th>Explana. Var.</th>
<th>Panel A: All M&amp;A Targets</th>
<th>Panel B: 100%-Cash M&amp;A Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(i)</td>
<td>(ii)</td>
</tr>
<tr>
<td>Intercept</td>
<td>0.016</td>
<td>0.017</td>
</tr>
<tr>
<td></td>
<td>0.54</td>
<td>0.59</td>
</tr>
<tr>
<td>$AVGr(\pi_g(+1, +10))$</td>
<td>-0.257</td>
<td>-0.147</td>
</tr>
<tr>
<td></td>
<td>-0.97</td>
<td>-0.42</td>
</tr>
<tr>
<td>$AVGr(\pi_\alpha(+1, +10))$</td>
<td>0.173</td>
<td>0.165</td>
</tr>
<tr>
<td></td>
<td>0.78</td>
<td>0.75</td>
</tr>
<tr>
<td>$AVGr(+1, +10)$</td>
<td>-0.058</td>
<td>-0.050</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.000</td>
<td>0.001</td>
</tr>
<tr>
<td>$Obs$</td>
<td>2372</td>
<td>2372</td>
</tr>
</tbody>
</table>
Table 7

Regressions of the Return Difference between Bidder Firms and Target Firms on the Probabilities of Informed Trading in Target Firms

This table reports the results of regressions of the M&A post-announcement average return difference between NYSE/AMEX-listed acquiring firms and target firms on the average daily conditional probabilities of target firms over the days after the M&A announcement date (M&AD). The sample period is from 1983 to 2013. The sample in the table includes only target firms that receive 100%-stock payment bids. The dependent variable is \( AVGDR(+11, FND) \), which is the average of daily return differences \( (R_{target} - R_{bidder}) \) from day +11 after the announcement date (M&AD+11) to the final date (FND), where FND is the effective date for completed M&As and the withdrawn date for withdrawn M&As. To calculate the daily return differences, each target firm is matched with its bidder firm both listed on the NYSE/AMEX. Other variables are defined as follows. \( AVG\pi_g(+1, +10) \): the average of daily \( \pi_g \)'s from day +1 to day +10 (relative to the initial M&A announcement date, M&AD), where \( \pi_g \) is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that the private information is good news; \( AVG\pi_b(+1, +10) \): the average of daily \( \pi_b \)'s from day +1 to day +10 (relative to the M&AD), where \( \pi_b \) is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that the private information is bad news; and \( AVG(1, +10) \): the average of daily stock returns from day +1 to day +10 (relative to the M&AD). The values in the first row for each explanatory variable are the coefficients from the regressions, and the values italicized in the second row of each variable are t-statistics. All coefficients are multiplied by 100. \( R^2 \) is the R-squared from the regressions. \( Obs \) is the number of target companies used in the regressions. Coefficients significantly different from zero at the significance levels of 1%, 5%, and 10% are indicated by ***, **, and *, respectively.

<table>
<thead>
<tr>
<th>Explana. Var.</th>
<th>(i)</th>
<th>(ii)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-0.068</td>
<td>-0.070</td>
</tr>
<tr>
<td></td>
<td>-1.51</td>
<td>-1.56</td>
</tr>
<tr>
<td>( AVG\pi_g (+1, +10) )</td>
<td>0.794 **</td>
<td>0.308</td>
</tr>
<tr>
<td></td>
<td>2.01</td>
<td>0.62</td>
</tr>
<tr>
<td>( AVG\pi_b (+1, +10) )</td>
<td>-0.272</td>
<td>-0.255</td>
</tr>
<tr>
<td></td>
<td>-0.89</td>
<td>-0.83</td>
</tr>
<tr>
<td>( AVG(1, +10) )</td>
<td>0.259</td>
<td>0.259</td>
</tr>
<tr>
<td></td>
<td>1.63</td>
<td></td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.023</td>
<td>0.035</td>
</tr>
<tr>
<td>( Obs )</td>
<td>228</td>
<td>228</td>
</tr>
</tbody>
</table>
Table 8  
Posterior Daily Probabilities of Informed Trading before Earnings Announcements

This table reports the average of daily posterior probabilities of informed trading before the earnings announcement date (EAD) for portfolios formed by sorting on $CAR(0, +1)$ in Panel A and on $SUE$ in Panel B. $CAR(0, +1)$ is the cumulative abnormal return (CAR) over two trading days (days 0 and +1) around the EAD, which is day 0. The daily abnormal return is the difference between a daily stock return and the daily CRSP (NYSE/AMEX/Nasdaq) value-weighted return. When the quarterly earnings were announced after the close (4:00 pm EST) on the IBES-reported announcement date, which is indicated by the time-stamps (available in IBES from 1999 on), the announcements are assumed to be made on the following trading day. $SUE$ is the standardized unexpected earnings, which is defined by the quarterly earnings surprise computed by assuming that the earnings per share (EPS) follows a seasonal random walk process [following Abarbanell and Lehavy (2007), special items are excluded from the Compustat-reported EPS]. For each firm each quarter, the two daily posterior probabilities ($\pi_g$ and $\pi_b$) are calculated for days around the quarterly EAD. To form decile portfolios, the component stocks are split into ten groups (with equal number of stocks) each quarter after being sorted in ascending order by $CAR$ (in Panel A) or $SUE$ (in Panel B). In each portfolio in each quarter, the cross-sectional mean of the relevant probabilities obtained above is computed, and finally the time-series average of the quarterly cross-sectional means is reported. The variables are defined as follows. $AVG\pi_g(-5, -1)$: the average of daily probabilities $\pi_g$ from day -5 to day -1 relative to the EAD, where $\pi_g$ is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that a good-news information event occurs on a given day; and $AVG\pi_b(-5, -1)$: the average of daily probabilities $\pi_b$’s from day -5 to day -1, where $\pi_b$ is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that a bad-news information event occurs on a given day. The last two columns in Panels A and B show the time-series average values for the differentials $(High - Low)$ between the values of $CAR$, $SUE$, and average probabilities in the highest $CAR$ or $SUE$ portfolio ($CAR10$ or $SUE10$) and in the lowest $CAR$ or $SUE$ portfolio ($CAR1$ or $SUE1$), together with the $t$-statistics to test the hypothesis that the time-series average of the differences equals zero. The average number of component stocks used in each quarter is 1,418.6 in Panel A (141.9 stocks on average in each portfolio in each quarter, or $141.9 \times 123$ quarter = 17,453.7 firm-quarters in each portfolio) and 1,202.4 in Panel B (120.2 stocks in each portfolio, or 14,784.6 firm-quarters in each portfolio). The sample period is from the second quarter of 1983 to the last quarter of 2013 (1983-Q2-2013-Q4) for NYSE/AMEX stocks.

<table>
<thead>
<tr>
<th>CAR Portfolios</th>
<th>Low</th>
<th>CAR1</th>
<th>CAR2</th>
<th>CAR3</th>
<th>CAR4</th>
<th>CAR5</th>
<th>CAR6</th>
<th>CAR7</th>
<th>CAR8</th>
<th>CAR9</th>
<th>CAR10</th>
</tr>
</thead>
<tbody>
<tr>
<td>$CAR(0, +1)$</td>
<td>-0.110</td>
<td>-0.045</td>
<td>-0.026</td>
<td>-0.014</td>
<td>-0.005</td>
<td>0.004</td>
<td>0.014</td>
<td>0.027</td>
<td>0.046</td>
<td>0.113</td>
<td>0.224</td>
</tr>
<tr>
<td>$AVG\pi_g(-5, -1)$</td>
<td>0.211</td>
<td>0.215</td>
<td>0.209</td>
<td>0.205</td>
<td>0.204</td>
<td>0.206</td>
<td>0.207</td>
<td>0.213</td>
<td>0.220</td>
<td>0.216</td>
<td>0.005</td>
</tr>
<tr>
<td>$AVG\pi_b(-5, -1)$</td>
<td>0.121</td>
<td>0.125</td>
<td>0.134</td>
<td>0.137</td>
<td>0.133</td>
<td>0.136</td>
<td>0.140</td>
<td>0.142</td>
<td>0.135</td>
<td>0.122</td>
<td>0.001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(High - Low)</th>
<th>value</th>
<th>$t$-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>$CAR(0, +1)$</td>
<td>0.224</td>
<td>31.26</td>
</tr>
<tr>
<td>$AVG\pi_g(-5, -1)$</td>
<td>0.005</td>
<td>1.40</td>
</tr>
<tr>
<td>$AVG\pi_b(-5, -1)$</td>
<td>0.001</td>
<td>0.27</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel B: Mean Values of Conditional Probabilities in the 10 Portfolios Formed by Sorting on SUE (1983-Q2-2013-Q4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>$SUE$</td>
</tr>
<tr>
<td>$AVG\pi_g(-5, -1)$</td>
</tr>
<tr>
<td>$AVG\pi_b(-5, -1)$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(High - Low)</th>
<th>value</th>
<th>$t$-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>$SUE$</td>
<td>0.380</td>
<td>6.03</td>
</tr>
<tr>
<td>$AVG\pi_g(-5, -1)$</td>
<td>0.044</td>
<td>10.27</td>
</tr>
<tr>
<td>$AVG\pi_b(-5, -1)$</td>
<td>-0.067</td>
<td>-18.77</td>
</tr>
</tbody>
</table>
Table 9
The Proportions of Firms with Good- and Bad-News Days in the Most Positive (SUE10) and Negative (SUE1) Surprise Portfolios around the EAD
This table reports the proportion of firms for which the daily conditional probabilities of informed trading are greater than or equal to 0.9 for the most positive (SUE10) and most negative (SUE1) surprise (measured by SUE) portfolios around the earnings announcement date (EAD). When the quarterly earnings were announced after the close (4:00 pm EST) on the IBES-reported announcement date, which is indicated by the time-stamps (available in IBES from 1999 on), the announcements are assumed to be made on the following trading days. SUE is the standardized unexpected earnings, which is defined by the quarterly earnings surprise computed by assuming, for forecasting purposes, that the earnings per share (EPS) follows a seasonal random walk process [following Abarbanell and Lehavy (2007), special items are excluded from the Compustat-reported EPS]. For each firm each quarter, the two daily conditional probabilities (π_g and π_b) are first assigned around the quarterly EAD. To form decile portfolios, the component stocks are split into ten groups (SUE1-SUE10) (with equal number of stocks) each quarter after being sorted in ascending order by SUE. The variables are defined as follows. π_g: the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that a good-news information event occurs on a given day; and π_b: the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that a bad-news information event occurs on a given day. The average number of component stocks used in each quarter is 1,202.4 (120.2 stocks in each portfolio, or 14,784.6 firm-quarters in each portfolio). The sample period is from the second quarter of 1983 to the last quarter of 2013 (1983:Q2-2013:Q4) for NYSE/AMEX stocks.

| Proportions of Firms with Daily Conditional Probabilities Greater than or Equal to 0.9 around the EAD for the Two Portfolios |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Portfolio | Category | d - 5 | d - 4 | d - 3 | d - 2 | d - 1 | d | d + 1 | d + 2 | d + 3 | d + 4 | d + 5 |
| SUE10 | π_g ≥ 0.9 | 0.152 | 0.151 | 0.162 | 0.181 | 0.226 | 0.341 | 0.269 | 0.218 | 0.197 | 0.186 | 0.181 |
| | π_b ≥ 0.9 | 0.042 | 0.040 | 0.041 | 0.045 | 0.063 | 0.131 | 0.115 | 0.099 | 0.095 | 0.090 | 0.082 |
| SUE1 | π_g ≥ 0.9 | 0.130 | 0.127 | 0.134 | 0.140 | 0.165 | 0.241 | 0.209 | 0.182 | 0.161 | 0.154 | 0.150 |
| | π_b ≥ 0.9 | 0.091 | 0.094 | 0.096 | 0.100 | 0.128 | 0.174 | 0.141 | 0.130 | 0.115 | 0.106 | 0.105 |
Table 10
Pre-EAD Informed Trading and the Earnings Announcement Return (CAR)
This table reports the results of Fama and MacBeth (1973) cross-sectional regressions (for positive and negative SUE separately), run quarterly, using the variables computed around the earnings announcement date (EAD). Panel A reports results for firms with positive SUE, Panel B for firms with negative SUE, and Panel C for all firms. The dependent variable is $CAR(0, +1)$, the cumulative abnormal return over two trading days (days 0 and +1) around the quarterly EAD. The explanatory variables are defined as follows. SUE: the standardized unexpected earnings, which is defined by the quarterly earnings surprise computed by assuming, for forecasting purposes, that the earnings per share (EPS) follows a seasonal random walk process [following Abarbanell and Lehavy (2007), special items are excluded from the Compustat-reported EPS]; $AVGR(-5, -1)$: the average of daily stock returns from day -5 to day -1; $AVGR^{*}(SUE)(-5, -1)$ if $SUE > 0$ and $AVGR(-5, -1)$ if $SUE < 0$; $SUE^{*}AVGR_{(i)}(-5, -1)$: the interaction term [SUE times $AVGR(-5, -1)$]; $DSUE$: 1 if $SUE < 0$, and 0 otherwise. The values in the first row for each explanatory variable are time-series averages of coefficients obtained from the quarterly cross-sectional regressions, and the values italicized in the second row of each variable are $t$-statistics computed based on Fama-MacBeth (1973). All coefficients are multiplied by 100. $Avg R^2$ is the average of adjusted R-squareds from quarterly regressions. $Avg Obs$ is the average number of companies used each quarter in the cross-sectional regressions. Coefficients significantly different from zero at the significance levels of 1%, 5%, and 10% are indicated by ***, **, and *, respectively. The sample period is from the second quarter of 1983 to the last quarter of 2013 (1983:Q2-2013:Q4) for NYSE/AMEX stocks.

<table>
<thead>
<tr>
<th>Pre-Announcement Informed Trading around the EAD and the Announcement Return (1983:Q2-2013:Q4)</th>
<th>Dep. Var. = $CAR(0, +1)$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Panel A: For SUE &gt; 0</td>
</tr>
<tr>
<td>Expla. Variables</td>
<td>(i)</td>
</tr>
<tr>
<td>Intercept</td>
<td>0.870 ***</td>
</tr>
<tr>
<td>SUE</td>
<td>2.171 **</td>
</tr>
<tr>
<td>2.01</td>
<td>2.36</td>
</tr>
<tr>
<td>$AVGR_{pi}(5, -1)$</td>
<td>-0.475 ***</td>
</tr>
<tr>
<td>-3.38</td>
<td>-3.34</td>
</tr>
<tr>
<td>SUE*$AVGR_{pi}(5, -1)$</td>
<td>-5.302 *</td>
</tr>
<tr>
<td>-1.90</td>
<td>-2.29</td>
</tr>
<tr>
<td>$AVGR(5, -1)$</td>
<td>-26.39 ***</td>
</tr>
<tr>
<td>-9.11</td>
<td>-9.42</td>
</tr>
<tr>
<td>$AVGR^{*}(SUE)(5, -1)$</td>
<td>-20.01 ***</td>
</tr>
<tr>
<td>Avg $R^2$</td>
<td>0.020</td>
</tr>
<tr>
<td>Avg Obs</td>
<td>695.0</td>
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Table 11
Post-EAD Informed Trading and Subsequent Stock Returns
This table reports the results of quarterly Fama-MacBeth (1973) cross-sectional regressions of the cumulative abnormal return over days +3 to +15 after the earnings announcement date (EAD) on the probabilities of informed trading after the EAD (from day +1 to day +2) for NYSE/AMEX-listed firms. The sample period is from 1983 to 2013. The dependent variable is $CAR(+3, +15)$, the cumulative abnormal return over trading days from day +3 to day +15 after the EAD. Other variables are defined as follows. $AVG\pi_g(+1, +2)$: the average of daily $\pi_g$’s from day +1 to day +2, where $\pi_g$ is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that the private information is good news; and $AVG\pi_k(+1, +2)$: the average of daily $\pi_k$’s from day 0+1 to day +2, where $\pi_k$ is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that the private information is bad news; $CAR(+1, +2)$: the cumulative abnormal return over two trading days (days +1 and +2) after the EAD. The values in the first row for each explanatory variable are the average coefficients from the quarterly regressions, and the values italicized in the second row of each variable are Fama-MacBeth (1973) t-statistics. All coefficients are multiplied by 100. $Adj R^2$ is the average of adjusted R-squareds from the quarterly regressions. Avg Obs is the average number of companies used each quarter in the regressions. Coefficients significantly different from zero at the significance levels of 1%, 5%, and 10% are indicated by ***, **, and *, respectively.

<table>
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<th>Explana. Var.</th>
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<th>(ii)</th>
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<tr>
<td>Intercept</td>
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<td>0.029</td>
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<td></td>
<td>0.21</td>
<td>0.11</td>
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<tr>
<td>$AVG\pi_g(+1, +2)$</td>
<td>0.574 ***</td>
<td>0.675 ***</td>
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<td></td>
<td>3.36</td>
<td>3.79</td>
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<tr>
<td>$AVG\pi_k(+1, +2)$</td>
<td>-0.314 *</td>
<td>-0.345 *</td>
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</tr>
<tr>
<td></td>
<td>-1.60</td>
<td>-1.82</td>
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<tr>
<td>$CAR(+1, +2)$</td>
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<td>$Adj R^2$</td>
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<td>Avg Obs</td>
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Figure 1. Time-Series Plots for the Monthly Cross-Sectional Averages of the PIN-related Parameters

This figure plots the time series of the equal-weighted cross-sectional mean of the PIN-related parameters estimated on a monthly basis for NYSE/AMEX-listed stocks over the 31 years (1983:03-2013:12). Figure 1(A) shows the time-series plot for $\alpha$ and $\delta$, Figure 1(B) does the same for $\mu$, and Figure 1(C) does the same for $\epsilon_b$ and $\epsilon_s$. The five PIN-related parameters are defined as follows: $\alpha$ (alpha in the legend) is the probability with which a private information event occurs on a given day; and $\delta$ (delta in the legend) is the probability with which a private information event, if it occurs on a given day, contains bad news; $\mu$ (mu in the legend) is the rate at which orders from informed traders arrive if the information event does occur; $\epsilon_b$ (eps_b in the legend) is the rate at which orders from uninformed buyers arrive; and $\epsilon_s$ (eps_s in the legend) is the rate at which orders from uninformed sellers arrive.

For estimating the monthly PIN-related parameters, each trade in the ISSM/TAQ databases is classified as buyer-initiated or seller-initiated via the Lee-Ready (1991) algorithm up to 2006 and the Holden-Jacobsen (2014) algorithm for the 2007-2013 period. The average number of component stocks used in each month is 2,798.2.
Figure 2. Time-Series Plots for the Monthly Cross-Sectional Averages of the Daily Posterior Probabilities

Panel A plots the time series of the equal-weighted monthly average of the two daily posterior probabilities for NYSE/AMEX stocks over the 31 years (1983:04-2013:12). Each day, πₐ and πₙ are estimated for each stock using the daily aggregated numbers of buyer-initiated trades and seller-initiated trades. For each firm, πₐ and πₙ are first averaged across trading days within each month, and then the cross-sectional mean of the monthly averages is calculated each month. Panel B plots the two posterior probabilities (πₐ and πₙ) at a daily frequency for Walgreen [Panel B(a)] and Xerox [Panel B(b)] from January 1984 to December 1985. For comparison purposes, the corresponding monthly unconditional probabilities [α(1−δ) (denoted by alpha*(1−delta) in the legend) and αδ (denoted by alpha*delta in the legend)] are overlaid within the daily plots, with the monthly values held constant over the days within the month. α(1−δ) is the monthly estimated unconditional probability that a good news information event occurs on a given day (α is the probability with which an information event occurs on a given day and δ is the probability with which the information event contains bad news); and αδ is the monthly estimated unconditional probability that a bad news information event occurs on a day. The average number of observations used in each month is 54,536.5 firm-days.

Panel A: Monthly Averages of the Daily Posterior Probabilities
Panel B: Plots of the Daily Conditional Probabilities and Quarterly Unconditional Probabilities for Some Individual Firms

(a) Walgreen: 1984:01-1985:12

(b) Xerox: 1984:01-1985:12
Figure 3. Daily Abnormal Stock Returns around the M&A Announcement Date for Bidder and Target Firms

The figure plots the averages of daily abnormal stock returns (relative to the S&P500 Index return) around the mergers and acquisitions (M&A) announcement date (M&AD: day $d$) for bidding (or acquiring) firms in Panel A and for target firms in Panel B. In Panel A, the average number of component stocks is 7,172 NYSE/AMEX-listed acquiring firms for the 1983-2013 period. In Panel B, the average number of component stocks is 2,623 NYSE/AMEX-listed target firms for the 1983-2013 period. The M&A-related variables are extracted from the SDC Platinum database for both completed and withdrawn M&A deals (tender offers) whose transaction values are greater than $50 million, and then matched with CRSP daily returns and other identification variables as well as the daily conditional probabilities estimated as in Table 1. $R_{\text{abn}}$ is defined as the daily abnormal stock return, which is the CRSP daily return in excess of the daily S&P500 Index return.

\[ R_{\text{abn}} \]

**Panel A: Bidding Firms**

< Figure 3(A): Average Abnormal Return ($R_{\text{abn}}$) around M&AD for Bidders >

**Panel B: Target Firms**

< Figure 3(B): Average Abnormal Return ($R_{\text{abn}}$) around M&AD for Targets >
Figure 4. Daily Abnormal Probabilities around the M&A Announcement Date for Bidder and Target Firms
The figure plots the averages of daily abnormal (or excess) probabilities ($\pi^{\text{abn}}_e$, $\pi^{\text{abn}}_g$, and $\pi^{\text{abn}}_b$) around the mergers and acquisitions (M&A) announcement date (M&AD: day $d$) for bidding (or acquiring) firms in Panel A and for target firms in Panel B. The abnormal probability for each component stock for each day around the event date (day $d-40$ to day $d+15$) is computed as the daily value of the probability ($\pi_e$, $\pi_g$, or $\pi_b$) minus the average of the daily probabilities over the 20 pre-event days (from day $d-60$ to day $d-41$). In Panel A, the average number of component stocks is 7,172 NYSE/AMEX-listed bidding firms for the 1983-2013 period. In Panel B, the average number of component stocks is 2,623 NYSE/AMEX-listed target firms for the 1983-2013 period. The M&A-related variables are extracted from the SDC Platinum database for both completed and withdrawn M&A deals (tender offers) whose transaction values are greater than $50$ million, and then matched with CRSP daily returns and other identification variables as well as the daily conditional probabilities estimated as in Table 1. The definitions of the variables are as follows. $\pi^{\text{abn}}_e$: the average of individual daily abnormal $\pi_e$'s, where $\pi_e$ is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that the private information event has occurred on a given day; $\pi^{\text{abn}}_g$: the average of individual daily abnormal $\pi_g$'s, where $\pi_g$ is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that the private information is good news; and $\pi^{\text{abn}}_b$: the average of individual daily abnormal $\pi_b$'s, where $\pi_b$ is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that the private information is bad news.

Panel A: Bidding Firms

Panel B: Target Firms
Panel A: Bidding Firms

< Figure 4(A2): Average $\pi_{g_{abn}}$ around M&AD >

< Figure 4(A3): Average $\pi_{b_{abn}}$ around M&AD >

Panel B: Target Firms

< Figure 4(B2): Average $\pi_{g_{abn}}$ around M&AD >

< Figure 4(B3): Average $\pi_{b_{abn}}$ around M&AD >
Figure 5. Daily Abnormal Posterior Probabilities of Informed Trading around the Quarterly Earnings Announcement Date

The figure plots the averages of daily abnormal (or excess) probabilities ($\pi_{abn}^{s}$, $\pi_{abn}^{g}$, and $\pi_{abn}^{b}$) around the quarterly earnings announcement date (EAD: day 0) for all firms in Panel A and by firm size (small and large firms) in Panel B. The abnormal probability for each component stock for each day around the event date (day $d-10$ to day $d+10$) is computed as the daily value of the probability ($\pi_e$, $\pi_g$, or $\pi_b$) minus the average of the corresponding daily probabilities over the 30 pre-event days (from day $d-40$ to day $d-11$). The definitions of the variables are as follows. $\pi_{abn}$: the average of individual daily abnormal $\pi_e$’s, where $\pi_e$ is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that the private information event has occurred on a given day; $\pi_{abn}^{g}$: the average of individual daily abnormal $\pi_g$’s, where $\pi_g$ is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that the private information is good news; $\pi_{abn}^{b}$: the average of individual daily abnormal $\pi_b$’s, where $\pi_b$ is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that the private information is bad news. In Panel A, the average number of component stocks (all firms) used in each quarter is 1,412.0. In Panel B, the component stocks are split into three groups (MV1-MV3) (with equal number of stocks) each quarter after being sorted in ascending order by the market capitalization, and then each day the average of abnormal probabilities of individual firms is computed for each group over the 10 days before and after the EAD. The averages of $\pi_{abn}^{s}$ and $\pi_{abn}^{g}$ for the small-sized group (MV1) are plotted in Figures 5(B1) and 5(B2), while the averages of them for the large-sized group (MV3) are plotted in Figures 5(B3) and 5(B4). In Panel B, the average of firm size for the small-sized group (MV1) is $137.6$ million and that for the large-sized group (MV3) is $8,915.6$ million. The average number of component stocks used in each of the size group each quarter in Panel B is 470.7. The sample period is from the second quarter of 1983 to the last quarter of 2013 (1983:Q2-2013:Q4) for NYSE/AMEX stocks.

Panel A: All Firms
Panel B: By Firm Size

< Figure 5(B1): Average $\pi^{abn}_g$ around EAD for the Small Firm Group >

< Figure 5(B2): Average $\pi^{abn}_g$ around EAD for the Small Firm Group >

< Figure 5(B3): Average $\pi^{abn}_g$ around EAD for Large Firm Group>

< Figure 5(B4): Average $\pi^{abn}_g$ around EAD for Large Firm Group>
Figure 6. Daily Abnormal Posterior Probabilities of Informed Trading around the Earnings Announcement Date for the Highest and Lowest SUE Portfolios

Figure 6(A) plots the averages of daily abnormal (or excess) probabilities of informed trading on good news ($\pi_{g, abn}^{abn}$) around the earnings announcement date (EAD: day $d$) within the highest SUE decile portfolio (SUE10), and Figure 6(B) does the same for the averages of daily abnormal probabilities of informed trading on bad news ($\pi_{b, abn}^{abn}$) within the lowest SUE decile portfolio (SUE1). The component stocks are split into ten groups (SUE1-SUE10 with equal number of stocks) each quarter after being sorted in ascending order by the standardized unexpected earnings (SUE) on the quarterly EAD, and then each day the average of abnormal probabilities of individual firms is computed over the 10 days before and after the EAD. The abnormal probability for each component stock for each day around the event date (day $d-10$ to day $d+10$) is computed as the daily value of the probability ($\pi_g$ or $\pi_b$) minus the average of the daily probabilities over the 30 pre-event days (from day $d-40$ to day $d-11$). The definitions of the variables are as follows. $\pi_{g, abn}^{abn}$: the average of individual daily abnormal $\pi_g$’s, where $\pi_g$ is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that the private information is good news; $\pi_{b, abn}^{abn}$: the average of individual daily abnormal $\pi_b$’s, where $\pi_b$ is the daily posterior probability (conditional on observing the number of daily buyer- and seller-initiated trades) that the private information is bad news. The average number of component stocks used in each of the SUE10 and SUE1 portfolios in each quarter is 120.2. The sample period is from the second quarter of 1983 to the last quarter of 2013 (1983:Q2-2013:Q4) for NYSE/AMEX stocks.