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Information Uncertainty and Intraday Market Responses to Corporate Disclosures: A Study of the Korean Stock Market*

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ABSTRACT

Using market microstructure data, this study analyzes intraday market responses to corporate disclosures subject to Regulation Fair Disclosure in Korea and examines whether the intraday market responses are affected by information uncertainty. We show that corporate news is incorporated into stock prices in an efficient and timely manner. We further document that positive stock returns and trading volume to good news disclosures are stronger for firms with higher information uncertainty. Overall, our evidence suggests that information uncertainty plays an important role in investors' reactions to corporate disclosures.

Keywords: intraday market responses; corporate disclosures; information uncertainty

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I. INTRODUCTION

The advances in technology over the last several decades have brought dramatic changes in capital markets. The accessibility to corporate information has considerably enhanced and the information processing costs have significantly declined, improving both the quantity and the quality of corporate information that information users can obtain. Furthermore, the development of trading system in securities markets has facilitated more efficient transactions between traders, and as a result, transaction costs have remarkably decreased. These changes have led to the improvement of stock market efficiency, accelerating the speed at which stock prices incorporate corporate information.

In this study, we explore intraday market responses to corporate disclosures and their association with information uncertainty in the Korean stock market. Prior studies mostly investigate the association between corporate news and stock returns using daily, weekly, or monthly returns data (See Ball and Brown 1968; Beaver 1968; Brown and Warner 1980, 1985; Dyckman, Philbrick, and Stephan 1984; Morse 1984).[1] However, recent studies show that stock price adjustments and investors' trading reactions to corporate news take place in a short time period (Busse and Green 2002; Muntermann and Guettler 2007; Lee, Cho, and Kim 2020). For example, Busse and Green (2002) document that the price of a stock starts to move several seconds after the stock is initially

1) One of the potential reasons that stock price reactions to corporate news take place for several days is because of the systematic differences in market responses to daytime disclosures and non-trading hour announcements (Francis, Pagach, and Stephan 1992). The market responses to corporate disclosures released during trading hours may occur within a day, but for those disclosed after trading session, market responses will appear in the subsequent trading day(s). Another possible reason is that the day at which after-hour corporate disclosure is made is often set to be even day 0 in many research settings due to the difficulty of obtaining the exact disclosure time, and this may create spurious drift in stock returns after corporate disclosures (Berkman and Truong 2009). To avoid potential systematic differences in market responses between daytime disclosures and non-trading hour disclosures, we delete non-trading hour disclosures from our sample. In addition, to remove the possibility that market responses are amplified due to double or multiple corporate disclosures, we exclude the disclosures overlapped with other disclosures within 91 minutes before and after the announcement.

mentioned in a CNBC TV program. Muntermann and Guettler (2007) find that stock prices respond to the release of ad hoc disclosures containing new information relevant to stock valuation within 30 minutes in Germany. Using Korean data, Lee, Cho, and Kim (2019) document that stock prices jump up immediately after the release of corporate disclosures and significant stock price returns remain mainly for two minutes. They also find that cumulative abnormal returns for two minutes after corporate disclosures are equivalent to those for sixty minutes, implying that using shorter return windows is necessary in order to avoid any potential confounding effects when examining the information content of corporate disclosures.

An obstacle to conducting intraday research in securities markets is that it is difficult to precisely capture the time point at which corporate news is first released in the market. To overcome this, we use corporate disclosures subject to Regulation Fair Disclosure (Reg FD), which has been implemented since November 1, 2002 in Korea. Korean companies are required to submit their corporate information subject to Reg FD in an electronic file to the Korean stock exchange or the Financial Supervisory Services (FSS) and then, the information is transmitted to the public without time lag by the electronic disclosure systems such as the Korea Investor's Network for Disclosure (KIND), operated by the Korean stock exchange, and the Data Analysis, Retrieval and Transfer (DART), run by the FSS (Lee 2009). Since corporate disclosures recorded in the electronic disclosure systems are time stamped, it enables us to conduct intraday analyses with specific time records of corporate disclosures. Furthermore, Reg FD prohibits managers from privately disclosing value-relevant information to select group of investors without also disclosing the same information publicly (SEC 2000; KSE 2002a, 2002b; Heflin, Subramanyam, and Zhang 2003; Lee, Cho, and Kim 2020).[2] Therefore, in our setting, using disclosures from corporations subject to Reg FD ensures that corporate news is initially made public, thus providing an ideal setting to study intraday market responses to these events.

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2) The material information denotes the information about earnings, mergers and acquisitions, tender offers, joint ventures, or changes in assets, new products or discoveries, or developments, changes in control or in management, change in auditors or auditor notification, events regarding the issuer's securities, and bankruptcies or receiverships (SEC 2000; KSE 2002a, 2002b; Chiyachantana et al. 2004; Lee 2009; Lee, Cho, and Kim 2020).

Another obstacle is the accessibility to intraday market data. However, this difficulty has been substantially relieved as market microstructure databases such as the Trade and Quote (TAQ) database become widely available. In Korea, real-time market data is available for purchase through market data vendors such as Koscom (data.koscom.co.kr) or from the *IFB/KSE Stock Transactions Database*, compiled and managed by the Institute of Finance and Banking (IFB) of Seoul National University. As the accessibility to market microstructure databases increases, the number of studies using intraday data is fast growing in finance and accounting (See Lee and Ready 1991; Mucklow 1994; Busse and Green 2002; Chordia, Roll, and Subrahmanyan 2005; Lee 2009; Lee, Cho, and Kim 2019).[3)]

In this study, we focus on the impact of information uncertainty on intraday market responses to corporate disclosures. In an efficient market, stock prices incorporate all information available in the market (Fama 1970). Accordingly, stock prices will not vary with firm characteristics after controlling for the effects of information contents. However, prior research documents that the magnitude of market responses to corporate disclosures can be affected by various factors such as information costs, transaction costs, and firm characteristics (Fama 1970; Fama 1991; Grossman and Stiglitz 1980). In particular, information acquisition costs in securities markets are positively associated with the level of information uncertainty, making it more difficult to estimate firm value (Easley and O'Hara 1987; Jiang, Lee, and Zhang 2005; Kalev et al. 2004). In other words, it would be more difficult for investors to obtain and interpret information about the firms with higher level of information costs (Jiang, Lee, and Zhang 2005; Zhang 2006a). Consequently, investors tend to demand more information about the firms with higher level of information uncertainty and corporate disclosures released by such firms may induce stronger reactions by investors (Barron et al. 2002).

Kim and Verrecchia (1991) document that the stock price change at the time of announcement is proportional to both the unexpected portion of the announcement and its relative importance across the posterior beliefs of traders, suggesting that the relative importance

3) Lee and Ready (1991) acclaims that intraday data opens "new frontiers" for financial market research.

of unexpected corporate news increases (decreases) in the precision of the announcement (preannouncement) information. Since the precision of the preannouncement information can be affected by information uncertainty, stock returns and trading volume will also be a function of the level of information uncertainty. On the contrary, investors' reaction to corporate disclosures may be weaker for firms with high level of information uncertainty if investors are overconfident and overweight (underweight) their private (public) signal (Daniel, Hirshleifer, and Subrahmanyam 1998).[4)]

We document that intraday stock returns to positive news disclosures reach the level of daily returns within 10 minutes. On the other hand, we observe positive intraday returns for 15 minutes for negative news disclosures, which appears to be underreactions by investors. After then, intraday stock returns (cumulative abnormal stock returns) become insignificant 30 (60) minutes after the release of information, The results also suggest that significant abnormal trading volume remains until the end of the trading sessions for both positive and negative news disclosures. Moreover, we find that cumulative abnormal order imbalance remains significant for 90 (15) minutes after positive (negative) news disclosures implying that stock prices incorporate new corporate information during the time and there is no further information leakage after then (Lee 1992). We also document that the level of information uncertainty is positively associated with the intraday stock returns to corporate disclosures. We further find that the positive relation between information uncertainty and stock returns is driven by firms with good news. We obtain similar results when we use abnormal trading volume instead of stock returns. An additional analysis suggests that investors tend to buy stocks of firms with good news when information uncertainty is high.

This study contributes to the literature by highlighting that market responses to corporate disclosures take place within a short time in a trading day. We overcome a potential obstacle of pinpointing the exact disclosure time in event studies by using the time-stamped records of corporate disclosures subject to Reg FD which forces firms to release their material information in a fair manner to the market. Our results shed light on the importance of using a short return window when examining the information contents of corporate

4) We thank an anonymous reviewer for the insightful comments.

news. Our findings suggest that stock prices incorporate corporate information in an efficient and timely manner in the Korean stock market.

The rest of the paper is organized as follows. Section II reviews the literature and develops our hypotheses. Section III provides research design. Section IV describes the data and descriptive statistics. Section V presents empirical results. Section VI provides a summary of our conclusions.

II. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Intraday Market Response to Corporate Disclosures

In perfect and efficient markets, stock prices reflect all available information and therefore, investors do not need to spend economic resources to obtain and process information (Fama 1970; Beaver 2002). Accordingly, stock prices will not vary with firm characteristics if the information contents are controlled. In the real world, however, obtaining and processing information is costly (Fama 1970; Grossman and Stiglitz 1980). Therefore, market participants who have informational advance over others are compensated through their arbitrage activities based on private information (Grossman and Stiglitz 1980).

The level of market efficiency can be tested by stock market responses to corporate news (Malkiel 1992; Campbell, Lo, and MacKinlay 1996). Accordingly, prior studies explore how fast stock prices incorporate new information released to the markets in order to test the degree of informational efficiency (See Patell and Wolfson 1984; Busse and Green 2002; Lee, Cho, and Kim 2020, etc.). While early studies such as Ball and Brown (1968), Beaver (1968), and Fama et al. (1969) examine informational efficiency in the markets using daily or longer-term market metrics, the speed with which stock prices incorporate new value-relevant information has been accelerated due to advances in technology over the last several decades (Busse and Green 2002). At the same time, the enhanced accessibility to market microstructure databases facilitates tests based on intraday data (Lee and Ready 1991).

Dann, Myers, and Raab Jr. (1977) is one of the earliest studies that use intraday data to examine the market responses to corporate information. They report that stock prices adjust to the unbiased estimates of the closing price of the event day within 15 minutes after the announcements of large block transactions. Since Dann, Myers, and Raab Jr. (1977), many studies investigate intraday stock price reactions to the public announcements in the capital markets. Patell and Wolfson (1984) examine the effects of earnings and dividend announcements on the intraday stock returns. They find that the stock returns earned by simple trading strategies disappear within five to ten minutes. Woodruff and Senchack, Jr. (1988) find that the average initial response to an earnings announcement occurs within 14 minutes after the announcement, and the major portion of the adjustments occurs within a few hours following an earnings news release. They also document that trading volume, transaction frequency, and transaction size are directly related to the absolute degree of surprise, and transaction frequency peaks quickly in the first half hour following an announcement and then, rapidly declines. Lee (1992) examines the directional trading volume reaction of small and large trades to different types of earnings news by separating trades into buyer- and seller-initiated activities. He finds that large trades show brief but intense buying (selling) tendency after good (bad) news. He also finds that small trades persistently exhibit purchasing tendency regardless of the news contents, but he could not fully explain this tendency of small trades.[5] Munterman and Guettler (2007) examine intraday stock price and trading volume reactions to ad hoc disclosures in Germany and document that stock prices react to ad hoc disclosures within 30 minutes after release and the trading volume takes more time to be adjusted.[6]

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5) Barber and Odean (2008) argue that individual investors tend to be net buyers of “attention-grabbing” stocks. They explain that this kind of result occurs because individual investors are more likely to buy rather than to sell the stocks that catch their attention. Since they do not have every single stock in the market, there exists the asymmetry between buying and selling tendencies. In other words, they can buy some stocks that grab their attention but cannot sell the stocks related to bad news if they do not own them.

6) On the other hand, Jennings and Starks (1985) argue that the stock price responses to high content announcements last for a long period of time than do the responses to low content events. They show that the effects of new information with high information content on stock prices dissipate on average within two days. They suspect that the rapid adjustments of stock prices in prior research such as Dann, Myers, and Raab Jr. (1977) and Patell and Wolfson (1984)

Another stream of research examines intraday stock price reactions to analysts' forecasts. Kim, Lin, and Slovin (1997) report that stock prices incorporate analysts' buy recommendations within 5 minutes before the stock market opens for NYSE/AMEX stocks and 15 minutes for NASDAQ stocks. Busse and Green (2002) also investigate the intraday responses of stock price and trading volume when a stock is mentioned on the Morning Call or Midday Call program on the prestigious financial news provider, CNBC. They find that stock prices respond to analysts' reports within seconds after a stock is initially mentioned and incorporate positive information in the reports within one minute.

Prior research also documents that the speed at which stock prices adjust to information has been accelerated due to the advances in information technology (Lee and Ready 1991; Lee 2009; Lee, Cho, and Kim 2020). Stock prices jump up immediately after the release of new corporate news and last only for few minutes (Lee 2009; Lee, Cho, and Kim 2020). The extensive availability of intraday market data accelerates intraday analyses on the effects of corporate disclosures, opening a new era of capital market research (Lee and Ready 1991). Prior findings also imply that it is important to use a short window when examining the effects of corporate disclosures in order to avoid any confounding effects.

Information Uncertainty and Market Responses

Information uncertainty is known as one of the factors that most significantly contribute to the pricing of assets in the capital markets (Kalev et al. 2004). Defining information uncertainty as "value ambiguity" or "the degree to which a firm's value can be reasonably estimated by even the most knowledgeable investors at reasonable costs," Jiang, Lee, and Zhang (2005) find that the firms with high level of information uncertainty earn lower future returns, and earnings momentum effects are much stronger for those firms. Zhang (2006a) investigates the role of information uncertainty on the cross-sectional stock returns and document that firms with higher information uncertainty earn relatively higher (lower) expected returns following good (bad) news. On the other hand, Zhang (2006b) explores the impact of information uncertainty on analysts'

may be due to a large number of uninformative information events.

forecasting activities and finds that greater information uncertainty causes more positive (negative) forecast errors and subsequent forecast revisions following good (bad) news. This implies that information uncertainty induces inefficient analyst forecasting behavior.

According to Kim and Verrecchia (1991), stock price changes at the time of corporate news announcement are proportional to both the expected portion of the announcement and its relative importance across the posterior beliefs of traders. They argue that the relative importance of the expected portion of the announcement increases (decreases) in the precision of the announcement (preannouncement) information. Since the precision of the preannouncement information is affected by information uncertainty, stock price changes and trading volume reactions are expected to be a function of the level of information uncertainty. On the other hand, Francis et al. (2007) provide an alternative explanation for post-earning announcement drift based on information uncertainty. After characterizing unexpected earnings as the level of information uncertainty, they argue that initial market reactions to the stocks with higher level of unexpected earnings are generally lower due to higher information uncertainty, and those stocks experience higher abnormal returns in the subsequent period.

Furthermore, investors may respond to corporate disclosure weakly if a firm has a high level of information uncertainty since they could be overconfident with their private information rather than with the public information (Daniel, Hirshleifer, and Subrahmanyam 1998). Therefore, it is an open empirical question whether information uncertainty strengthens investors' reaction to corporate news or not.

Hypothesis Development

Based on the theory and empirical evidence of prior literature, we predict that intraday stock price returns and trading volume reactions to corporate disclosures will be greater in the presence of information uncertainty is higher, leading to the following hypotheses.

> **H1a:** The intraday stock returns to corporate disclosures will be greater when information uncertainty is higher.
>
> **H1b:** The intraday trading volume reactions to corporate disclosures will be greater when information uncertainty is higher.

H1c: Investors will buy (sell) stocks rather than sell (buy) stocks for good (bad) news when the level of information uncertainty is high.

In testing the above hypotheses, we also test whether the impact of information uncertainty vary with the characteristics of corporate news. Specifically, we test whether the impact of information uncertainty on intraday market responses to corporate disclosures is greater for good news.

III. RESEARCH DESIGN

To examine intraday stock price responses, we use cumulative abnormal return ($CAR_{[0,+10]}$), estimated from 0 minute to +10 minute. Lee, Cho, and Kim (2020) show that stock price jumps up immediately after the release of corporate information subject to Reg FD and then, small significant positive stock returns last until 7 minutes after the disclosure. For the reason, we set the return test window to cover the time during which abnormal stock price reactions primarily take place and thus, investigate stock price responses to corporate disclosures from 0 minute to +10 minute.

For investors' trading volume, we use cumulative abnormal turnover ($CATO_{[0,+30]}$) estimated by aggregating abnormal turnover from 0 to +30 minutes. Lee, Cho, and Kim (2020) document that abnormal trading volume to corporate disclosures lasts for about 80 (40) minutes after the release of positive (negative) disclosures, but most of notable trading reactions occur within 30 minutes. In the sensitivity analysis, we also test our hypotheses using *CATO* measured for 60 and 90 minutes.

We also examine investors' directional trading responses using cumulative abnormal *NETBUY* ($CANETBUY_{[0,+15]}$) measured for 15 minutes after the release of corporate disclosures. Lee (1992) points out that trading volume metrics used in prior studies do not provide information about the direction of trading volume. However, order imbalance classifies each transaction into either buyer-initiated or seller-initiated trade and indicates investors' directional trading reactions (Holthausen, Leftwich, and Mayers 1987; Hasbrouck 1988; Blume, Mackinlay, and Terker 1989; Harris 1989; Lee and Ready 1991; Lee 1992). Furthermore, order imbalance can be used to check whether there exists information leakage before public announcements of corporate disclosures. For the reason, the duration and adjustment path of order imbalance provides new implications on how quickly stock prices incorporate new corporate information (Lee 1992).

To measure order imbalance, we identify who initiates a trade, i.e., whether a buyer initiates a trade or whether a seller initiates a trade.[7] Prior studies generally use Lee and Ready (1991) algorithm to calculate order imbalance, which classify the direction of a transaction by comparing the trade price to adjacent trades or to the bid/ask prices of the prevailing quote.[8] On the other hand, Odders-White (2000) defines the initiator as an investor who places his or her order later than other investors involved. Therefore, we follow the approach of Odders-White (2000) and define the initiator of a transaction as the investor who places his or her order last chronologically.[9]

To test the relation between information uncertainty and intraday market responses, we measure information uncertainty using the principal component analysis (Jiang, Lee, and Zhang 2005; Zhang 2006a). The first variable *IU*1 is the common factor based on firm size, residual return volatility, analyst coverage, and market-to-book ratio.[10] The second variable *IU*2 is estimated using all four variables used to estimate *IU*1 and firm age.[11] When estimating *IU*1 and *IU*2,

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7) An initiator of a trade is an investor who demands immediate execution of a trade (Lee and Ready 1991; Lee 1992; Odders-White 2000).

8) The method of determining the direction of a trade by comparing the transaction price to the preceding one is called "tick test." Under the tick test, a trade is classified as a buyer-(seller-) initiated trade if the price is higher (lower) than the preceding price. When the price is the same as the adjacent one, the initiation of a trade is determined by comparing with the last price change. For example, if the price changes upwardly (downwardly) before the previous transaction, it is characterized as a buyer-(seller-) initiated trade. This tick test has been used when quote data is not available (Lee and Ready 1991).

9) Theissen (2001) documents that Odders-White (2000)'s algorithm classifies 85% of the initiation of trades correctly, while Lee and Ready (1991)'s algorithm classifies 72.8% of the initiation of trades correctly.

10) Residual return volatility is measured as the variance of residuals in the market model estimated using weekly stock and market returns, where weekly returns are measured from Thursday to Wednesday to mitigate nonsynchronous trading or bid-ask bounce effects in daily prices (Zhang 2006a).

11) Our results are qualitatively similar when we estimate the information uncertainty proxy using firm size, residual volatility, and analyst coverage only

we modify the underlying variables to be the fractional rankings (between 0 and 1) except for analyst coverage, a greater value of which represents higher level of information uncertainty.[12)]

To investigate the incremental effects of information uncertainty (IU) on intraday stock returns for which good news is released, we employ the following model.

$$CAR_{it[0,+10]} = \beta_0 + \beta_1 IU_{it} + \beta_2 GOOD_{it} + \beta_3 IU_{it}{*}GOOD_{it} + \beta_4 LnPRICE_{it} + \beta_5 CATO_{it[0,+10]} + \beta_6 BETA_{it} + \varepsilon_{it} \quad (1)$$
$$CAR_{it[0,+10]} = \prod_{\tau=0}^{+10\text{min}} (1 + AR_{it\tau}) - 1$$
$$AR_{it\tau} = R_{it\tau} - R_{Mt\tau}$$

where IU is one of our two measures of information uncertainty (i.e., $IU1$ and $IU2$); $GOOD$ an indicator variable for good news; $R_{it\tau}$ is stock return of firm i at minute τ to corporate disclosures released at event time t; $R_{Mt\tau}$ is market return at minute τ to corporate disclosures released at event time t; $AR_{it\tau}$ is abnormal stock return of firm i at minute τ to corporate disclosures released at event time t, measured as the difference between $R_{it\tau}$ and $R_{Mt\tau}$; $CAR_{it[0,+10]}$ is calculated as cumulated returns of $(1 + AR_{it\tau})$ for 10 minutes after the release of corporate disclosures minus one. In Equation (1) we include the one-day prior closing price ($LnPRICE$) to control for the price effect on stock transactions. It represents a transaction cost because investors, especially individual investors, generally trade a small amount of money for stocks and thus, are less likely to trade stocks at a high price (Chung, Choe, and Kho 2009). The trading volume ($CATO$) is also controlled because trading volume is significantly associated with the changes in stock prices (Karpoff 1987; Busse and Green 2002; Chordia, Roll, and Subrahmanyam 2005).[13)] We also include firm beta ($BETA$) in the model because it is expected to be positively associated with CAR. We include industry and year fixed effects to control for variations in CAR across industries and

(untabulated).

12) To make a greater value of firm size and firm age represent higher level of information uncertainty, we deduct the fractional rankings of those variables from one. In addition, the indicator variable of analyst coverage is deducted from one.

13) Busse and Green (2002) document that stock prices incorporate new corporate information more quickly as investors trade stocks more intensively after the release of corporate news.

years. If information uncertainty affects intraday returns for stocks with good news to a larger extent, we expect that the interaction term between the information uncertainty proxy and good news indicator ($IU_{it}*GOOD_{it}$) will be significantly positive.

We examine the effects of information uncertainty on the intraday trading volume by estimating the following regression.

$$CATO_{it[0,+30]} = \beta_0 + \beta_1 IU_{it} + \beta_2 GOOD_{it} + \beta_3 IU_{it}*GOOD_{it} + \beta_4 LnPRICE_{it} + \beta_5 |CAR_{it[0,+30]}| + \beta_6 BETA_{it} + \varepsilon_{it} \quad (2)$$

$$CATO_{it[0,+30]} = \sum_{\tau=0}^{+30\text{min}} ABTURNOVER_{it\tau}$$

$$ABTURNOVER_{it\tau} = TURNOVER_{it\tau} - \overline{TURNOVER_{it}}$$

$$TURNOVER_{it\tau} = \frac{Trading\ Volume_{it\tau}}{\#\ of\ Shares\ Outstanding_{it}}$$

$$\overline{TURNOVER_{it}} = \frac{1}{15}\sum_{\tau=-30\text{ min}}^{-16\text{ min}} TURNOVER_{it\tau}$$

where $TURNOVER_{it\tau}$ is trading volume of firm i at minute τ to corporate disclosures released at event time t, divided by the number of outstanding shares of firm i at event time t; $\overline{TURNOVER_{it}}$ is average trading volume for 15 minutes from -30 minute to -16 minute of firm i to corporate disclosures released at event time t; $ABTURNOVER_{it\tau}$ is abnormal turnover, measured as the difference between $TURNOVER_{it\tau}$ and $\overline{TURNOVER_{it}}$; $CATO_{it[0,+30]}$ is calculated as cumulated $ABTURNOVER_{it\tau}$ for 30 minutes from 0 to +30 minute after the release of corporate disclosures. In Equation (2), we control for the absolute value of CAR ($|CAR|$) because the prior studies document that the abnormal trading volume is positively correlated with the absolute value of abnormal stock returns (Karpoff 1987; Kim and Verrecchia 1991).[14)]

When the corporate news is released, investors tend to react to the news in a certain direction depending on the news. For example, investors are more likely to purchase (sell) stocks when they have good (bad) news. We examine whether information uncertainty affects the direction of investors' transactions by estimating the following model.

14) Grossman and Stiglitz (1980) argue that trading volume is affected by stock returns because the price system facilitates the transfer of information from informed investors to uninformed investors.

$$CANETBUY_{it[0,+15]} = \beta_0 + \beta_1 IU_{it} + \beta_2 GOOD_{it} + \beta_3 IU_{it}*GOOD_{it} + \beta_4 LnPRICE_{it} + \beta_5 CAR_{it[0,+15]} + \beta_6 BETA_{it} + \varepsilon_{it} \quad (3)$$

$$CANETBUY_{it[0,+15]} = \sum_{0}^{+15\ min} ABNETBUY_{it\tau}$$

$$ABNETBUY_{it\tau} = NETBUY_{it\tau} - \overline{NETBUY_{it}}$$

$$NETBUY_{it\tau} = \frac{BUY_{it\tau} - SELL_{it\tau}}{\#\ of\ Shares\ Outstanding_{it}} *100$$

$$\overline{NETBUY_{it}} = \frac{1}{15} \sum_{\tau=-30\ min}^{-16\ min} NETBUY_{it\tau}$$

where $BUY_{it\tau}$ ($SELL_{it\tau}$) is buyer- (seller-) initiated trade of firm i at minute τ to corporate disclosures released at event time t; $NETBUY_{it\tau}$ is the difference between $BUY_{it\tau}$ and $SELL_{it\tau}$ of firm i at minute τ to corporate disclosures released at event time t, divided by the number of outstanding shares of firm i at event time t; $\overline{NETBUY_{it}}$ is average *NETBUY* for 15 minutes from -30 minute to -16 minute of firm i to corporate disclosures released at event time t; $ABNETBUY_{it\tau}$ is abnormal *NETBUY*, measured as the difference between $NETBUY_{it\tau}$ and $\overline{NETBUY_{it}}$; $CANETBUY_{it[0,+15]}$ is calculated as cumulated $ABNETBUY_{it\tau}$ for 15 minutes from 0 to +15 minute after the release of corporate disclosures.

IV. DATA AND DESCRIPTIVE STATISTICS

Data

We hand-collect time-stamped records and contents of corporate disclosures subject to Reg FD from the KIND (Korea Investor's Network for Disclosure) system. The sample period of this study is from November 1, 2002 to December 31, 2004. We delete observations released during non-trading hours (or days). We also eliminate observations with disclosures which are corrected and re-disclosed later and disclosures that are overlapped with another disclosure within 91 minutes before and after the disclosure time. Our final sample contains 1,930 observations.

The intraday data used in this study are obtained from the *IFB/KSE Stock Transactions Database*.[15] The database contains detailed

15) The raw data is provided by the Korea Stock Exchange (*KSE*) and compiled by the

information about each transaction executed on the Korea Stock Exchange (*KSE*) (Choe, Kho, and Stulz 1999, 2005; Lee 2009; Lee, Cho, and Kim 2020).[16] The other financial statement data are obtained from the *KIS-VALUE LIBRARY*, and the daily stock prices are collected from the *KISRI-SD*.

Descriptive Statistics

Table 1 shows the types and the frequency of corporate disclosures subject to Reg FD used in this study. The types of disclosures are predetermined by the regulation, but we reclassify them into 7 different categories based on their contents as follows: 1) future business plans, 2) earnings forecasts, 3) preannouncements of earnings performance, 4) major managerial issues, 5) dividend payments, 6) mixtures, and 7) others. Earnings-related corporate disclosures including earnings forecasts and preannouncements of earnings performance are characterized as being positive, negative or mixed either by comparing with analysts' consensus at one day before corporate disclosures or actual earnings performance in the previous period, if there exists no analyst following (Skinner 1994).[17] All other corporate disclosures are characterized as either positive or negative depending on the contents of the corporate news (Busse and Green 2002). Table 1 indicates that positive disclosures dominate our sample. Specifically, 1,200 (62.18%) disclosures are characterized as positive news, while only 182 (9.43%) disclosures classified as bad news. The number of negative news is relatively small, partly because companies do not have incentives to voluntarily disclose negative news. Particularly, litigation risk in Korea is substantially low compared to that in other countries such as the U.S. and thus, even if managers withhold negative news, they may not be often involved in lawsuits. Moreover, managers tend to stra-

Institute of Finance and Banking (*IFB*) of Seoul National University (Choe, Kho, and Stulz 1999, 2005).

16) The Korea Stock Exchange (KSE) and the Korea Securities Dealers Automated Quotations (KOSDAQ) have been merged into the Korea Exchange (KRX) in January 2005.

17) "Mixed" indicates that a corporate disclosure could be characterized differently depending upon the criteria. For example, earnings news may be classified as "positive" if it is compared with revenue but as "negative" if it is compared with net income.

Table 1. Types and frequencies of corporate disclosures subject to Reg FD from Nov 1, 2002 to Dec. 31, 2004

Disclosure type	Frequency					
	Positive	Negative	Mixed	N/A	Missing	Total
Future business plans	625	2	0	8	0	635
Earnings forecasts	72	26	25	1	2	126
Preannouncements of earnings performance	349	132	413	1	26	921
Major managerial issues	32	0	0	39	0	71
Dividend payments	42	0	0	1	0	43
Mixtures	79	22	18	5	0	124
Others	1	0	0	9	0	10
Total (%)	1,200 (62.18)	182 (9.43)	456 (23.63)	64 (3.32)	28 (1.45)	1,930 (100.00)

Notes: 1) Corporate disclosures titled "future business plans" contain the information about a startup of new business, development of new technology, new product, or new market, a strategic alliance, investment in new project, new contract, new construction, acquisition of new equipment, restructuring plans, etc.

2) Corporate disclosures titles "earnings forecasts" include managerial earnings forecasts of sales, operating income (loss), ordinary income (loss), or net income (loss).

3) Corporate disclosures titled "preannouncements of earnings performance" include the announcements of earnings performance in advance before companies publicly release the information through financial statements. "Earnings forecasts" are mainly issued during a fiscal year while "preannouncements" are released after the end of a fiscal year.

4) Corporate disclosures titled "major managerial issues" include those informing the present conditions of firms, business environments, etc. "Dividend payments" disclose dividend-related information.

5) "Mixtures" include more than two different types of corporate disclosures, for example, earnings forecasts with dividend payments or future business plans with the preannouncements of earnings.

6) "Others" include the corporate disclosures subject to Reg FD such as "requests for inquired disclosures," or "responses to requests for inquired disclosures."

tegically choose the timing of corporate disclosures, and they may release bad news during non-trading sessions such as nights, weekends, or public holidays to avoid investors' immediate negative reactions (Patell and Wolfson 1982; Gennotte and Trueman 1996; Graham, Harvey, and Rajgopal 2005; Dellavigna and Pollet 2009; Truong 2010; Michaely, Rubin, Vedrashko 2016).

Table 2 reports intraday returns and daily returns after the release of corporate disclosures subject to Reg FD. In Panel A, we compare between intraday stock returns and daily stock returns. According to the results, the average daily return for good news disclosures is 1.58% and significant in terms of nonparametric empirical bootstrap *p*-value (Barclay and Litzenberger 1988; Busse and Green 2002; Lee 2009). Intraday stock returns increase up to 10 minutes after disclosures and then, gradually decrease. More importantly, intraday stock returns reach the level close to daily returns within 10 minutes after the release of corporate news. In contrast, we find that the average daily return for bad news disclosures is 0.20% but insignificant. As shown in Lee (2009) and Lee, Cho, and Kim (2020), negative corporate disclosures induce small positive returns just after the announcements, but they lose statistical significance within 15 minutes after the disclosures. The average intraday stock returns after the release of negative corporate disclosures are greater than the average daily return and remain significant for about 15 minutes. Overall, the results indicate that stock returns reflect the information contained in corporate disclosures within a day.

Panel B of Table 2 reports the frequency of signs of intraday and daily stock returns for positive and negative corporate news. For good news disclosures, the number of daily observations with a positive sign is 753 (62.75%) and that with a negative sign is 392 (32.67%). 55 (4.58%) observations have zero daily returns. For bad news disclosures, 86 (47.25%) daily observations have a positive sign, 90 (49.45%) daily observations have a negative sign, and 6 (3.30%) daily observations have a zero return. On the other hand, the percentage of intraday observations with a positive sign for good news disclosures is higher than that of daily stock returns with a positive sign for good news disclosures across all the intraday return test windows except for the window from 0 minute to the end of trading session. Particularly, for good news disclosures, the frequency of intraday stock returns from 0 minute to +1 minute with a positive sign is 871 and its percentage is 71.75%. In that case, the frequency (percentage) with a negative sign is 101 (8.42%) and 238 observations have a zero return (19.83%). Only the intraday return test window from 0 minute to the end of trading session has 730

Table 2. Comparison between intraday and daily stock returns after corporate disclosures

Panel A: Intraday return vs. daily return

	Time interval	*N*	Intraday return (IR)	Daily return (DR)	Percentage (%) = (IR/DR) * 100
Positive disclosures	0, +1 min	1,200	0.0135 **	0.0158 **	85.44
	0, +2 min	1,200	0.0137 **		86.71
	0, +5 min	1,200	0.0149 **		94.30
	0, +10 min	1,200	0.0165 **		104.43
	0, +15 min	1,200	0.0162 **		102.53
	0, +30 min	1,200	0.0149 **		94.30
	0, +60 min	1,200	0.0133 **		84.18
	0, +90 min	1,061	0.0116 **		73.42
	0, Adj. closing price	1,200	0.0102 **		64.56
Negative disclosures	0, +1 min	182	0.0033 **	0.0020	165.00
	0, +2 min	182	0.0026 **		130.00
	0, +5 min	182	0.0018 *		90.00
	0, +10 min	182	0.0027 *		135.00
	0, +15 min	182	0.0034 **		170.00
	0, +30 min	182	0.0017		85.00
	0, +60 min	182	0.0015		75.00
	0, +90 min	153	0.0003		15.00
	0, Adj. closing price	182	-0.0006		N/A

Panel B: Frequency of signs of intraday stock returns and daily stock returns

	Time interval	Frequency of signs					
		Intraday stock returns			Daily stock returns		
		Positive (%)	Negative (%)	Zero (%)	Positive (%)	Negative (%)	Zero (%)
Positive disclosures	0, +1	861 (71.75)	101 (8.42)	238 (19.83)	753 (62.75)	392 (32.67)	55 (4.58)
	0, +2	849 (70.75)	140 (11.67)	211 (17.58)			
	0, +5	868 (72.33)	172 (14.33)	160 (13.34)			
	0, +10	844 (70.33)	204 (17.00)	152 (12.67)			

Table 2. (continued)

	Time interval	Frequency of signs					
		Intraday stock returns			Daily stock returns		
		Positive (%)	Negative (%)	Zero (%)	Positive (%)	Negative (%)	Zero (%)
	0, +15	840 (70.00)	244 (20.33)	116 (9.67)			
	0, +20	849 (70.75)	255 (21.25)	96 (8.00)			
	0, +30	812 (67.67)	282 (23.50)	106 (8.83)			
	0, +60	779 (67.92)	321 (26.75)	100 (8.33)			
	0, +90	672 (63.34)	309 (29.12)	80 (7.54)			
	0, Adj. closing price	730 (60.83)	388 (32.33)	82 (6.84)			
Negative disclosures	0, +1	88 (48.36)	47 (25.82)	47 (25.82)	86 (47.25)	90 (49.45)	6 (3.30)
	0, +2	81 (44.51)	49 (26.92)	52 (28.57)			
	0, +5	88 (48.35)	59 (32.42)	35 (19.23)			
	0, +10	86 (47.25)	67 (36.81)	29 (15.93)			
	0, +15	82 (45.06)	71 (39.01)	29 (15.93)			
	0, +20	82 (45.05)	73 (40.11)	27 (14.84)			
	0, +30	82 (45.05)	80 (43.96)	20 (10.99)			
	0, +60	80 (43.95)	77 (42.31)	25 (13.74)			
	0, +90	67 (43.79)	65 (42.48)	21 (13.73)			
	0, Adj. closing price	79 (43.41)	87 (47.80)	16 (8.79)			

Notes: Both intraday returns (IR) and daily returns (DR) are calculated by using the following equation.

$$R_{it} = \frac{P_{it} - P_{it-1}}{P_{it-1}}$$

where P_{it} indicates the price of a stock of firm i at time t. Closing price is the stock price determined in the last transaction before the end of a trading session and adjusted closing price indicates that the closing stock price is adjusted for corporate actions such as dividends and stock splits. ** and * denote statistical significance at the 1% and 5% level using one-sided nonparametric empirical bootstrap p-value, respectively.

Table 3. Cumulative abnormal returns (*CAR*), turnover (*CATO*), and net buy (*CANETBUY*) after corporate disclosures

	Time interval	*CAR*	*CATO*	*CANETBUY*
Positive disclosures	0, +1 min	0.0135 **	0.0016 **	0.0010 **
	0, +2 min	0.0134 **	0.0024 **	0.0012 **
	0, +5 min	0.0148 **	0.0035 **	0.0014 **
	0, +10 min	0.0164 **	0.0056 **	0.0017 **
	0, +15 min	0.0160 **	0.0068 **	0.0018 **
	0, +30 min	0.0147 **	0.0087 **	0.0017 **
	0, +60 min	0.0132 **	0.0102 **	0.0013 **
	0, +90 min	0.0117 **	0.0107 **	0.0009 **
	0, Adj. closing price	0.0098 **	0.0110 **	0.0003
Negative disclosures	0, +1 min	0.0035 **	0.0003 **	0.0002 **
	0, +2 min	0.0028 **	0.0004 **	0.0002 **
	0, +5 min	0.0021 **	0.0007 **	0.0002 **
	0, +10 min	0.0032 **	0.0012 **	0.0002 **
	0, +15 min	0.0037 **	0.0015 **	0.0002 *
	0, +30 min	0.0026 *	0.0022 **	0.0001
	0, +60 min	0.0024 *	0.0027 **	0.0002
	0, +90 min	0.0012	0.0027 **	0.0002
	0, Adj. closing price	-0.0005	0.0033 **	-0.0001

Notes: 1) *CAR* is estimated as follows:

$$CAR_{it[0,+\omega]} = \prod_{\tau=0}^{+\omega}\left(1 + AR_{it\tau}\right) - 1$$

$$AR_{it\tau} = R_{it} - R_{Mt}$$

where $R_{it\tau}$ is stock return of firm i at minute τ to corporate disclosure released at event time t and $R_{Mt\tau}$ is market return at minute τ to corporate disclosure released at event time t. $AR_{it\tau}$ is abnormal stock return of firm i at minute τ to corporate disclosure released at event time t, measured as the difference between $R_{it\tau}$ and $R_{Mt\tau}$. $CAR_{it[0,+\omega]}$ is calculated as cumulated returns of $(1 + AR_{it\tau})$ for ω minutes after the release of corporate disclosure minus one.

2) *CATO* is estimated as follows:

$$CATO_{it[0,+\omega]} = \prod_{\tau=0}^{+\omega}\left(1 + ABTURNOVER_{it\tau}\right) - 1$$

$$ABTURNOVER_{it\tau} = TURNOVER_{it\tau} - \overline{TURNOVER_{it}}$$

Table 3. (continued)

$$TURNOVER_{it\tau} = \frac{Trading\,Volume_{it\tau}}{\#of\ Shares\,Outstanding_{it}}$$

$$\overline{TURNOVER_{it}} = \frac{1}{15}\sum_{\tau=-30min}^{-16min} TURNOVER_{it\tau}$$

where $TURNOVER_{it\tau}$ is trading volume of firm i at minute τ to corporate disclosure released at event time t, divided by the number of outstanding shares of firm i at event time t and $\overline{TURNOVER_{it}}$ is average trading volume for 15 minutes from -30 minute to -16 minute of firm i to corporate disclosure released at event time t. $ABTURNOVER_{it\tau}$ is abnormal turnover, measured as the difference between $TURNOVER_{it\tau}$ and $\overline{TURNOVER_{it}}$. $CATO_{it[0,+\omega]}$ is calculated as cumulated $ABTURNOVER_{it\tau}$ for ω minutes from 0 to $+\omega$ minute after the release of corporate disclosure.

3) *CANETBUY* is estimated as follows:

$$CANETBUY_{it[0,+\omega]} = \sum_{\tau=0}^{+\omega} ANETBUY_{it\tau}$$

$$ABNETBUY_{it\tau} = NETBUY_{it\tau} - \overline{NETBUY_{it}}$$

$$NETBUY_{it\tau} = \frac{(BUY_{it\tau} - SELL_{it\tau})}{\#of\ Shares\,Outstanding_{it}}$$

$$\overline{NETBUY_{it}} = \frac{1}{15}\sum_{\tau=-30min}^{-16min} NETBUY_{it\tau}$$

where $BUY_{it\tau}$ ($SELL_{it\tau}$) is buyer-(seller-) initiated trade of firm i at minute τ to corporate disclosure released at event time t. $NETBUY_{it\tau}$ is the difference between $BUY_{it\tau}$ and $SELL_{it\tau}$ of firm i at minute τ to corporate disclosure released at event time t, divided by the number of outstanding shares of firm i at event time t. $\overline{NETBUY_{it}}$ is average *NETBUY* for 15 minutes from -30 minute to -16 minute of firm i to corporate disclosure released at event time t. $ABNETBUY_{it\tau}$ is abnormal *NETBUY*, measured as the difference between $NETBUY_{it\tau}$ and $\overline{NETBUY_{it}}$. $CANETBUY_{it[0,+\omega]}$ is calculated as cumulated $ABNETBUY_{it\tau}$ for ω minutes from 0 to $+\omega$ minute after the release of corporate disclosure.

4) Closing price is the stock price determined in the last transaction before the end of a trading session and adjusted closing price indicates that the closing stock price is adjusted for corporate actions such as dividends and stock splits.

5) ** and * denote statistical significance at the 1% and 5% level using one-sided nonparametric empirical bootstrap *p*-value, respectively.

(60.83%) observations with a positive sign, which is fewer than that of daily return observations.

For bad news disclosures, 90 (49.45%) observations have a negative sign, 86 (47.25%) have a positive sign, and 6 (3.30%) observations have a zero return. The results show that the frequency of intraday returns with a negative sign is fewer than that of daily returns with a negative sign across all the return test windows. As the intraday return window length becomes longer, the frequency of intraday stock returns with a negative sign increases. The percentage of intraday stock returns with a negative sign from 0 minute to the end of trading session is 47.80%, similar to that of daily stock returns. It indicates that investors appear to underreact to negative news.

Table 3 reports the average magnitudes of cumulative abnormal returns (*CAR*), cumulative abnormal turnover (*CATO*), and cumulative abnormal net-buy (*CANETBUY*). For good news, *CAR*s are significantly positive until the end of the event day. More specifically, *CAR* reaches the highest value (0.0164) at around +10 minutes after corporate disclosures and after then, gradually decreases. For bad news, *CAR* is significant until +60 minutes after the release of corporate disclosures. In this case, *CAR* has the highest value (0.0037) at around +15 minutes. *CATO* is significantly positive irrespective of the characteristics of corporate disclosures and continuously increases as time passes. On the other hand, *CANETBUY* shows that investors appear to buy stocks irrespective of the characteristics of corporate disclosures. However, the average *CANETBUY* becomes insignificant when it is calculated from 0 minute to the end of trading session for good news disclosure. For bad news disclosures, *CANETBUY* becomes insignificant +15 minutes after corporate disclosures.

Overall, the results show that notable stock price reactions take place in minutes, particularly for good news disclosures, and abnormal trading volume continues until the end of trading sessions but increases highest at around +10 minutes (+30 minutes) for good (bad) news disclosures. On the other hand, the results of *CANETBUY* imply that stock price incorporates new corporate information quickly within a trading session (Lee 1992).

We report descriptive statistics of our regression variables in Table 4. Panel A presents the summary statistics. Note that we use *CAR* for 10 minutes ($CAR_{[0,+10]}$), *CATO* for 30 minutes ($CATO_{[0,+30]}$), and *CANETBUY* for 15 minutes ($CANETBUY_{[0,+15]}$), as the dependent variables in our regressions. The mean value of $CAR_{[0,+10]}$ and $CATO_{[0,+30]}$ are 0.0134 and 0.0079, respectively. The mean (median) value of $CANETBUY_{[0,+15]}$ is 0.0015 (0.0002). Turning to our information uncertainty variables, the mean value of *IU*1 and *IU*2 are

Table 4. Descriptive statistics and correlation table

Panel A: Descriptive statistics

Variable	N	Mean	Median	Min	Max
$CAR_{i[0,+10]}$	1,930	0.0134	0.0048	-0.0292	0.1187
$CATO_{i[0,+30]}$	1,930	0.0075	0.0009	-0.0051	0.1050
$CANETBUY_{i[0,+15]}$	1,930	0.0015	0.0002	-0.0035	0.0229
*IU*1	1,810	0.3516	0.2178	-0.4079	1.5622
*IU*2	1,810	0.2971	0.1812	-0.4989	1.5465
GOOD	1,382	0.8683	1.0000	0.0000	1.0000
LnPRICE	1,930	8.8838	8.8465	5.7526	12.9042
BETA	1,871	0.9765	0.9718	-0.1695	2.3970

Panel B: Correlations

	$CAR_{i[0,+10]}$	$CATO_{i[0,+30]}$	$CANETBUY_{i[0,+15]}$	*IU*1	*IU*2	*GOOD*	*LnPRICE*	*BETA*
$CAR_{i[0,+10]}$	1.0000	0.5486 (<.0001)	0.5961 (<.0001)	0.3467 (<.0001)	0.3439 (<.0001)	0.2099 (<.0001)	-0.3338 (<.0001)	-0.0340 (0.1514)
$CATO_{i[0,+30]}$	0.4732 (<.0001)	1.0000	0.5943 (<.0001)	0.5337 (<.0001)	0.5263 (<.0001)	0.1391 (<.0001)	-0.5307 (<.0001)	-0.0206 (0.3845)
$CANETBUY_{i[0,+15]}$	0.4404 (<.0001)	0.7776 (<.0001)	1.0000	0.3682 (<.0001)	0.3634 (<.0001)	0.2334 (<.0001)	-0.4121 (<.0001)	-0.0382 (0.1070)
*IU*1	0.4025 (<.0001)	0.4182 (<.0001)	0.3595 (<.0001)	1.0000	0.9973 (<.0001)	0.1131 (<.0001)	-0.7165 (<.0001)	-0.0107 (0.6573)
*IU*2	0.3982 (<.0001)	0.4102 (<.0001)	0.3534 (<.0001)	0.9982 (<.0001)	1.0000	0.1111 (<.0001)	-0.7110 (<.0001)	-0.0106 (0.6588)
GOOD	0.1762 (<.0001)	0.1236 (<.0001)	0.1356 (<.0001)	0.1301 (<.0001)	0.1268 (<.0001)	1.0000	-0.1072 (<.0001)	-0.0209 (0.4565)
LnPRICE	-0.3490 (<.0001)	-0.4395 (<.0001)	-0.4019 (<.0001)	-0.6826 (<.0001)	-0.6797 (<.0001)	-0.1021 (0.0001)	1.0000	-0.1064 (<.0001)
BETA	-0.0319 (0.1785)	-0.0231 (0.3285)	-0.0399 (0.0919)	-0.0075 (0.7560)	-0.0053 (0.8246)	-0.0194 (0.4881)	-0.0956 (<.0001)	1.0000

Notes: All variables except for dummy and group variables are winsorized at the top and bottom 1%. We delete observations with negative book value. Pearson (Spearman) correlation coefficients are presented below (above) the diagonal.

0.3516 and 0.2971, respectively. The mean value of *GOOD* is 0.8683, indicating that there are more positive corporate disclosures than negative corporate disclosures in our sample. The average of the logarithm of one-day prior closing stock price (*LnPRICE*) is 8.8838, whereas the mean value of firm beta (*BETA*) is 0.9765.

Panel B of Table 4 reports the correlations among our regression variables. We find that $CAR_{[0,+10]}$ is positively correlated with our information uncertainty proxies (*IU*1 and *IU*2), implying that stocks with higher information uncertainty tend to experience higher cumulative abnormal returns. We also find that $CAR_{[0,+10]}$ is positively (negatively) correlated with *GOOD* (*LnPRICE* and *BETA*), although its correlation with *BETA* is insignificant. The correlations of $CATO_{[0,+30]}$ and $CANETBUY_{[0,+15]}$ are similar to those of $CAR_{[0,+10]}$.

V. EMPIRICAL RESULTS

In this section, we examine the association between information uncertainty and the intraday market responses to corporate disclosures. Panel A of Table 5 presents the results of the regression analysis on the effects of information uncertainty on $CAR_{[0,+10]}$. In models (1) and (3), we find that information uncertainty (*IU*) is positively associated with $CAR_{[0,+10]}$, consistent with our first hypothesis. The positive coefficients on *IU* indicates that the level of information uncertainty of firms positively affects intraday stock returns to corporate disclosures. The results in models (2) and (4) show that the interaction variable between information uncertainty and good news (*IU***GOOD*) is positive and significant, implying that the impact of good corporate news on intraday stock returns becomes greater when a firm's information environment is poor. The insignificant coefficients on *IU* in models (2) and (4) indicate that information uncertainty does not affect cumulative abnormal returns when firms release negative news.[18)]

Panel B of Table 5 reports the results of using $CATO_{[0,+30]}$ as the dependent variable. Similar to Panel A, in models (1) and (3) we find that information uncertainty (*IU*) is positively associated with $CATO_{[0,+30]}$, suggesting that investors tend to trade more as a firm's information uncertainty increases. In addition, the results in models (2) and (4) indicate that the interaction term between *IU* and *GOOD*

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18) We extend the intraday return test window to 60 minutes and 90 minutes and conduct the regression analyses on the association between information uncertainty and intraday market responses (*CAR* and *CATO*). We find that the association loses significance as the test window becomes longer.

Table 5. Information uncertainty and the intraday market responses to corporate disclosures

Panel A: Information uncertainty and $CAR_{[0,+10]}$

	Prediction	*IU*1		*IU*2	
		Model (1)	Model (2)	Model (3)	Model (4)
Intercept	?	-0.0018 (-0.2103)	-0.0006 (-0.0724)	-0.0008 (-0.0890)	0.0001 (0.0089)
IU	+	0.0100 *** (5.1745)	0.0037 (1.0356)	0.0099 *** (5.1385)	0.0037 (1.0438)
GOOD	+	0.0069 *** (4.9912)	0.0054 *** (4.4886)	0.0069 *** (5.0131)	0.0059 *** (4.8183)
*IU*GOOD*	+		0.0070 * (1.9156)		0.0069 * (1.9223)
LnPRICE	-	-0.0007 (-1.1725)	-0.0007 (-1.1434)	-0.0007 (-1.2408)	-0.0007 (-1.2107)
CATO	+	0.9658 *** (10.3048)	0.9573 *** (10.1926)	0.9689 *** (10.3385)	0.9606 *** (10.2300)
BETA	+	-0.0000 (-0.0057)	-0.0000 (-0.0274)	0.0000 (0.0155)	-0.0000 (-0.0059)
Industry FE		Included	Included	Included	Included
Year FE		Included	Included	Included	Included
N		1,252	1,252	1,252	1,252
Adj. R^2 (%)		33.78	38.69	33.75	38.63
F-value		40.88 ***	33.87 ***	40.83 ***	33.84 ***

Panel B: Information uncertainty and $CATO_{[0,+30]}$

	Prediction	*IU*1		*IU*2	
		Model (1)	Model (2)	Model (3)	Model (4)
Intercept	?	0.0236 *** (3.6060)	0.0244 *** (3.7246)	0.0242 *** (3.6886)	0.0248 *** (3.7722)
IU	+	0.0026 ** (2.5405)	-0.0020 (-1.3248)	0.0024 ** (2.3812)	-0.0020 (-1.3890)
GOOD	+	0.0015 *** (2.8973)	0.0005 (1.0747)	0.0015 *** (2.2901)	0.0008 * (1.7486)
*IU*GOOD*	+		0.0050 *** (3.1884)		0.0049 *** (3.1927)
LnPRICE	-	-0.0023 *** (-4.9218)	-0.0023 *** (-4.8930)	-0.0024 *** (-4.9794)	-0.0023 *** (-4.9496)

Table 5. (continued)

	Prediction	*IU*1		*IU*2	
		Model (1)	Model (2)	Model (3)	Model (4)
|CAR|	+	0.3275 *** (8.8036)	0.3248 *** (8.7525)	0.3285 *** (8.8448)	0.3259 *** (8.7964)
BETA	+	-0.0005 (-0.5377)	-0.0005 (-0.5556)	-0.0005 (-0.5378)	-0.0005 (-0.5554)
Industry FE		Included	Included	Included	Included
Year FE		Included	Included	Included	Included
N		1,252	1,252	1,252	1,252
Adj. R^2 (%)		37.85	37.97	37.82	37.92
F-value		48.62 ***	46.04 ***	48.55 ***	45.96 ***

Panel C: Information uncertainty and $CANETBUY_{[0,+15]}$

	Prediction	*IU*1		*IU*2	
		Model (1)	Model (2)	Model (3)	Model (4)
Intercept	?	0.0084 *** (4.3874)	0.0085 *** (4.4541)	0.0085 *** (4.4499)	0.0086 *** (4.4952)
IU	+	0.0003 (1.1629)	-0.0005 (-1.0708)	0.0003 (1.0348)	-0.0005 (0.0001)
GOOD	+	0.0003 * (1.9191)	0.0001 (0.6751)	0.0003 * (1.9320)	0.0001 (1.1973)
*IU*GOOD*	+		0.0009 * (1.9449)		0.0008 * (1.8479)
LnPRICE	-	-0.0006 *** (-4.9077)	-0.0006 *** (-4.8805)	-0.0006 *** (-4.9893)	-0.0006 *** (-4.9622)
CAR	+	0.0552 *** (7.6111)	0.0548 *** (4.5672)	0.0554 *** (7.6270)	0.0550 *** (7.5870)
BETA	-	-0.0004 * (-1.9208)	-0.0004 * (-1.9234)	-0.0004 * (-1.9252)	-0.0004 * (-1.9275)
Industry FE		Included	Included	Included	Included
Year FE		Included	Included	Included	Included
N		1,252	1,252	1,252	1,252
Adj. R^2 (%)		30.07	30.13	30.05	30.09
F-value		34.62 ***	32.73 ***	34.59 ***	32.68 ***

Notes: 1) *CAR* is estimated as follows:

Table 5. (continued)

$$CAR_{it[0,+10]} = \prod_{\tau=0}^{+10}\left(1 + AR_{it\tau}\right) - 1$$

$$\ldots\ AR_{it\tau} = R_{it} - R_{Mt}$$

where $R_{it\tau}$ is stock return of firm i at minute τ to corporate disclosure released at event time t and $R_{Mt\tau}$ is market return at minute τ to corporate disclosure released at event time t. $AR_{it\tau}$ is abnormal stock return of firm i at minute τ to corporate disclosure released at event time t, measured as the difference between $R_{it\tau}$ and $R_{Mt\tau}$. $CAR_{it[0,+\omega]}$ is calculated as cumulated returns of (1 + $AR_{it\tau}$) for ω minutes after the release of corporate disclosure minus one.

2) *CATO* is estimated as follows:

$$CATO_{it[0,+30]} = \prod_{\tau=0}^{+30}\left(1 + ABTURNOVER_{it\tau}\right) - 1$$

$$ABTURNOVER_{it\tau} = TURNOVER_{it\tau} - \overline{TURNOVER_{it}}$$

$$TURNOVER_{it\tau} = \frac{Trading\,Volume_{it\tau}}{\#\,of\ Shares\,Outstanding_{it}}$$

$$\overline{TURNOVER_{it}} = \frac{1}{15}\sum_{\tau=-30min}^{-16min} TURNOVER_{it\tau}$$

where $TURNOVER_{it\tau}$ is trading volume of firm i at minute τ to corporate disclosure released at event time t, divided by the number of outstanding shares of firm i at event time t and $\overline{TURNOVER_{it}}$ is average trading volume for 15 minutes from -30 minute to -16 minute of firm i to corporate disclosure released at event time t. $ABTURNOVER_{it\tau}$ is abnormal turnover, measured as the difference between $TURNOVER_{it\tau}$ and $\overline{TURNOVER_{it}}$. $CATO_{it[0,+\omega]}$ is calculated as cumulated $ABTURNOVER_{it\tau}$ for ω minutes from 0 to +ω minute after the release of corporate disclosure.

3) *CANETBUY* is estimated as follows:

$$CANETBUY_{it[0,+15]} = \sum_{\tau=0}^{+15} ABNETBUY_{it\tau}$$

$$ABNETBUY_{it\tau} = NETBUY_{it\tau} - \overline{NETBUY_{it}}$$

$$NETBUY_{it\tau} = \frac{\left(BUY_{it\tau} - SELL_{it\tau}\right)}{\#\ of\ \ Shares\ \ Outstanding_{it}}$$

$$\overline{NETBUY_{it}} = \frac{1}{15}\sum_{\tau=-30min}^{-16min} NETBUY_{it\tau}$$

where $BUY_{it\tau}$ ($SELL_{it\tau}$) is buyer-(seller-) initiated trade of firm i at

Table 5. (continued)

minute τ to corporate disclosure released at event time t. $NETBUY_{it\tau}$ is the difference between $BUY_{it\tau}$ and $SELL_{it\tau}$ of firm i at minute τ to corporate disclosure released at event time t, divided by the number of outstanding shares of firm i at event time t. $\overline{NETBUY_{it}}$ is average $NETBUY$ for 15 minutes from -30 minute to -16 minute of firm i to corporate disclosure released at event time t. $ABNETBUY_{it\tau}$ is abnormal $NETBUY$, measured as the difference between $NETBUY_{it\tau}$ and $\overline{NETBUY_{it}}$. $CANETBUY_{it[0,+\omega]}$ is calculated as cumulated $ABNETBUY_{it\tau}$ for ω minutes from 0 to $+\omega$ minute after the release of corporate disclosure.

4) *IU*1 is a factor for information uncertainty, which is measured by the principal component analysis. This study uses four variables including firm size, residual volatility, analyst coverage, and market-to-book ratio to extract this factor. *IU*2 is extracted by the principal component analysis using five variables including firm size, residual volatility, analyst coverage, firm age, and market-to-book ratio. *GOOD* represents positive corporate news. *LnPRICE* is the closing price of one trading day prior to corporate disclosure date. *CATO* is cumulative abnormal turnover estimated from 0 minute to +30 minute. *BETA* is a firm beta at the end of the previous year computed by the market model using 60 month returns requiring at least 30 non-missing observations. *CAR* is cumulative abnormal returns estimated from 0 minute to +10 minute. $|CAR|$ is the absolute value of *CAR*.

5) *t*-statistics are corrected for heteroscedasticity, and are provided in the parentheses (White 1980). ***, **, and * denote significant at the 1%, 5%, and 10% level, respectively.

is positive and significant, implying that information uncertainty has an increasing impact on $CATO_{[0,+30]}$ when firms release good news. The coefficients on *LnPRICE* are negative and significant across all models, indicating that investors are less likely to trade stocks when the one-day prior closing stock price is high. The absolute value of *CAR* is positively related to *CATO*, consistent with prior studies (Karpoff 1987; Kim and Verrecchia 1991). Firm beta (*BETA*) does not affect abnormal trading volume in all models.

Panel C of Table 5 presents the results of the relation between information uncertainty and investors' trading direction, $CANETBUY_{[0,+15]}$. In contrast to Panel A and B, we find that the coefficients on *IU* are insignificant in models (1) and (3). The positively significant coefficients on *IU***GOOD* and insignificant coefficients on *IU* and

GOOD in models (2) and (4) suggest that investors are net purchaser when a firms' information uncertainty is high and good news is released. Similar to Panel B, the coefficients on *LnPRICE* are negatively significant in all models, indicating that investors tend to sell stocks when the one-day prior closing stock price is high. The results also suggest that investors are likely to buy stocks with high cumulative abnormal return.

VI. CONCLUSION

As the information technology advances in financial markets, the speed with which corporate news is incorporated into stock prices has been greatly accelerated. Recent studies show that market responses to corporate information events primarily take place within a day. In this study, we focus on intraday market responses to corporate disclosures and examine whether they vary with the degree of information uncertainty. Corporate disclosure events subject to Reg FD in Korea enable us to capture the timing of corporate disclosures accurately in intraday analyses and thus, provide a unique opportunity to measure intraday market reactions to corporate information (Lee, Cho, and Kim 2020).

Using a sample of Korean firms over the period of November 2002 to December 2004, we show that intraday stock returns to positive news disclosures reach the level of daily returns within 10 minutes. Investors appear to underreact to negative news for 15 minutes after the disclosures. Intraday stock returns become insignificant within 30 minutes after bad news disclosures, while cumulative abnormal returns become insignificant 60 minutes after the disclosures. Significant abnormal trading volume remains until the end of the trading sessions for both positive and negative news disclosures.

We also document that cumulative abnormal order imbalance remains significant only for 90 (15) minutes after positive (negative) news disclosures. We show that information uncertainty is positively associated with intraday stock returns (*CAR*), but the impact exists only for good news disclosures. We obtain similar results when we use trading volume (*CATO*) and order imbalance (*CANETBUY*) to proxy for market responses to corporate disclosures. We find that as the time interval becomes longer, the coefficients in the models for *CATO* and *CANETBUY* become less significant, suggesting that it would be more difficult to find the effects of information uncertainty on intraday market responses to corporate disclosures when long return windows are used. It also implies that corporate information is incorporated into stock prices quickly within a day.

We contribute to the finance and accounting literature by highlighting the intraday market responses to corporate disclosures and their association with information uncertainty. The results of our study should be of interest to policy makers and regulators because they show that information leakage is not noticeably observed before public announcements, indicating that Reg FD in Korea works well by making firms to disclose their material information in a fair manner.

Our findings are subject to several caveats. First, we assume that firms disclose their material information in compliance with Reg FD. However, firms may still provide their privately information to select parties, which could lead to information leakage before public announcements. If this is the case, it will be difficult to pinpoint the exact disclosure time at which corporate news is released to the market, and market responses to corporate disclosures may not be fully captured by intraday returns. Second, our characterization of corporate disclosures as positive or negative news may be subject to measurement error. Careful interpretation is needed for the results of positive and negative news.

APPENDIX

Variable Definitions

Variables	Definition
CAR	$CAR_{it[0,+\omega]} = \prod_{\tau=0}^{+\omega}(1 + AR_{it\tau}) - 1$ … $AR_{it\tau} = R_{it} - R_{Mt}$ where $R_{it\tau}$ is stock return of firm i at minute τ to corporate disclosure released at event time t; $R_{Mt\tau}$ is market return at minute τ to corporate disclosure released at event time t; $AR_{it\tau}$ is abnormal stock return of firm i at minute τ to corporate disclosure released at event time t, measured as the difference between $R_{it\tau}$ and $R_{Mt\tau}$; $CAR_{it[0,+\omega]}$ is calculated as cumulated returns of (1 + $AR_{it\tau}$) for ω minutes after the release of corporate disclosure minus one.

Variables	Definition
CATO	$CATO_{it[0,+\omega]} = \prod_{\tau=0}^{+\omega}\left(1 + ABTURNOVER_{it\tau}\right) - 1$ $\ldots\ ABTURNOVER_{it\tau} = TURNOVER_{it\tau} - \overline{TURNOVER_{it}}$ $\ldots\ TURNOVER_{it\tau} = \frac{Trading\,Volume_{it\tau}}{\#\ of\ \ Shares\ \ Outstanding_{it}}$ $\ldots\ \overline{TURNOVER_{it}} = \frac{1}{15}\sum_{\tau=-30min}^{-16min} TURNOVER_{it\tau}$ where $TURNOVER_{it\tau}$ is trading volume of firm i at minute τ to corporate disclosure released at event time t, divided by the number of outstanding shares of firm i at event time t; $\overline{TURNOVER_{it}}$ is average trading volume for 15 minutes from -30 minute to -16 minute of firm i to corporate disclosure released at event time t; $ABTURNOVER_{it\tau}$ is abnormal turnover, measured as the difference between $TURNOVER_{it\tau}$ and $\overline{TURNOVER_{it}}$; $CATO_{it[0,+\omega]}$ is calculated as cumulated $ABTURNOVER_{it\tau}$ for ω minutes from 0 to $+\omega$ minute after the release of corporate disclosure.
CANETBUY	$CANETBUY_{it[0,+\omega]} = \sum_{\tau=0}^{+\omega} ABNETBUY_{it\tau}$ $\ldots\ ABNETBUY_{it\tau} = NETBUY_{it\tau} - \overline{NETBUY_{it}}$ $\ldots\ NETBUY_{it\tau} = \frac{\left(BUY_{it\tau} - SELL_{it\tau}\right)}{\#\ of\ \ Shares\ \ Outstanding_{it}}$ $\ldots\ \overline{NETBUY_{it}} = \frac{1}{15}\sum_{\tau=-30min}^{-16min} NETBUY_{it\tau}$ where $BUY_{it\tau}$ ($SELL_{it\tau}$) is buyer- (seller-) initiated trade of firm i at minute τ to corporate disclosure released at event time t; $NETBUY_{it\tau}$ is the difference between $BUY_{it\tau}$ and $SELL_{it\tau}$ of firm i at minute τ to corporate disclosure released at event time t, divided by the number of outstanding shares of firm i at event time t; $\overline{NETBUY_{it}}$ is average *NETBUY* for 15 minutes from -30 minute to -16 minute of firm i to corporate disclosure released at event time t; $ABNETBUY_{it\tau}$ is abnormal *NETBUY*, measured as the difference between $NETBUY_{it\tau}$ and $\overline{NETBUY_{it}}$. $CANETBUY_{it[0,+\omega]}$ is calculated as cumulated $ABNETBUY_{it\tau}$ for ω minutes from 0 to $+\omega$ minute after the release of corporate disclosure.
*IU*1	A factor for information uncertainty measured by the principal component analysis based on firm size, residual volatility, analyst coverage, and market-to-book ratio.

Variables	Definition
IU2	A factor for information uncertainty measured by the principal component analysis based on firm size, residual volatility, analyst coverage, firm age, and market-to-book ratio.
GOOD	An indicator variable which equals one for positive corporate news disclosure, zero otherwise.
LnPrice	Closing price of one trading day prior to corporate disclosure date.
BETA	Firm beta at the end of the previous year computed by the market model using 60 month returns requiring at least 30 non-missing observations.

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