The Discovery Role of Analysts

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Abstract: Analysts' functions are divided into discovery and interpretation roles, but separating between the two is non-trivial. Relying on Livnat and Zhang (2012) we isolate discovery revisions and examine their determinants, association with equity price efficiency, and analysts' skill. We find that discovery and interpretation revisions are determined by the richness of the news environment and that the two roles are substitutes. We also document that discovery revisions—a proxy for private information—is associated with lower equity return volatilities, implying that equity price informativeness increases with private information. Finally, we show that analysts who engage in more discovery provide more accurate and timelier forecasts, and that investors react more strongly to their recommendation changes, which suggests that investors prefer these analysts' opinions.

Keywords: Analysts, Discovery Role, Corporate Disclosure, Price Efficiency, Analysts Skill

I. Introduction

Financial analysts play a central role in the capital market by interpreting information and by discovering information. In their interpretation role, analysts use their expertise and knowledge to transform corporate disclosure and other corporate-related news such as press releases into reports of forecasts and recommendations that investors then use in making investment decisions (e.g., Ivkovic and Jegadeesh 2004; Asquith et al. 2005; Chen et al. 2010). In their discovery role, analysts obtain private information through various channels other than corporate disclosures, and they use their expertise and knowledge to analyze the information and update their forecasts and recommendations. Recent studies suggest that one useful way of analyzing how analysts perform their task is by partitioning analysts' discovery and interpretation roles (Ivkovic and Jegadeesh 2004; Chen et al. 2010; Livnat and Zhang 2012; Rubin et al. 2016). While these studies differ in their research design, the common conjecture of these studies is that forecast revisions reports that *follow* the arrival of corporate announcements are defined as those that are associated with the interpretation role, whereas forecast revisions that do not follow corporate announcements are associated with the discovery role. These studies then focus on the market reaction to the two types of forecasts to determine which role of analysts is more valued by investors.[1]

Following Livnat and Zhang (2012), we assume that forecast revisions not preceded by public information directly related to the firm are considered as discovery revisions. We include the following as public information directly related to the firm: corporate filings (10-K/Q, 8-K, and Proxy Statement), news about the firm (e.g., press release), and forecast revision by another analyst following the firm. Hence, according

[1] Huang et al. (2016) take a different approach to isolate the two roles. They implement advanced textual analysis methods to analyze the textual content of analyst research reports relative to the information embedded in the textual content of the preceding corporate disclosures to determine the extent of information interpretation and discovery in the research report.

to this definition, discovery revisions reflect primarily private information of the analyst.[2] Following Rubin et al. (2016), we define interpretation revisions that follow unanticipated news as revisions associated with the interpretation role.[3]

The purpose of this study is threefold. First, we examine the interplay between discovery and interpretation revisions. We argue that the incentives of analysts to engage in discovery and the importance of the discovery role are negatively related to the richness of the information environment and, as a result, the two roles are essentially substitutes—firms with poor information environment are likely to attract more discovery revisions, and these revisions are likely to be economically important. On the other hand, private information is likely to play a smaller role as the richness of the information environment increases, and the main activities of analysts would be to interpret information. Second, we analyze whether and how discovery forecast revisions (which represent the outcome of private information acquired and analyzed by analysts) are associated with price efficiency—in general and particularly with volatility of equity returns around earnings announcements. While the impact of discovery revisions on equity return volatility in general can be either positive or negative, it is likely that discovery revisions are negatively associated with volatility around earnings announcements, implying that the extent to which prices reflect information increases with the extent of private information disseminated via discovery revisions. Third, we measure discovery skill based on the frequency of analysts' discovery revisions, and we

[2] It is important to note that by private information we mean information that is not public and directly related to the firm. In other words, private information related to the specific firm can include public information related to other companies such as earnings reports of competitors.

[3] Rubin et al. (2016) argue that analysts' reports following corporate announcements are indicative of interpretation skill only if the corporate announcement is unanticipated. This is because forecast revision following an anticipated corporate event, such as the earnings announcement, is potentially affected by the analyst's ability to predict the news. Consequently, the reaction to anticipated news is likely affected by both the discovery and interpretation skills of the analyst, making it difficult to isolate each of these skills by examining forecasts around anticipated news. In contrast, unanticipated announcements by definition cannot be predicted; therefore, the reaction to such announcements depends only on the analyst's ability to interpret the information. We treat forecast revision following earnings news and following other analysts' revisions as separate categories. See discussion in Section 4 below.

examine whether this measure is associated with cross-sectional differences in forecast properties and market reaction to analysts' recommendations.

We find that about 12.6% of the forecast revisions are attributed to discovery and that these revisions are economically informative. In addition, the likelihood of discovery revisions is negatively related to the amount of news directly concerning the firm and to the proportion of interpretation revisions. These results indicate that public and private information are substitute and that the two roles are substitute as well. In other words, the greater the amount of news, the greater is the likelihood that analysts engage in information interpretation and the lower is the likelihood that analysts provide private information. For instance, sorting firms to quintiles based on news count, we find that only 2.3% (28.7%) of total forecast revisions are attributed to discovery (interpretation), whereas for firms in the lowest news quintile the proportion of discovery revisions is close to 50% (15.8%).

Notwithstanding the negative relation between discovery and interpretation revisions at the firm-year level, in a separate analysis we examine the relation between the two roles at the analyst-firm-level. We find that about 38% of the analysts provide at least one discovery revision during the year – that is, the majority of the analysts do not provide discovery, and about 28% of the analysts do not provide neither discovery nor interpretation revision. Further, we observe positive correlation between the number of discovery and interpretation revisions at the analyst-firm-year level, that is, analysts that provide discovery revisions are also more likely to provide interpretation revision.

The analysis of the relation between the extent of discovery revisions and price efficiency reveals that both the volatility of equity returns, in general and around earnings announcement days, are negatively associated with discovery revisions. In addition, not only the level of equity return volatility is lower but also the difference

between the volatility around earnings announcement and volatility in the period immediately before and after the earnings announcement window. These findings indicate that discovery revisions increase price efficiency in the sense that prices reflect more information, thereby resulting in lower volatility around earnings announcement and in general. Indeed, to support our conjecture that discovery revisions enhance the informativeness of prices, we examine the relation between discovery revisions and forecast error and forecast dispersion. We find that companies with greater proportion of discovery revisions have lower forecast error and lower dispersion. These results indicate that discovery revisions are associated with more accurate and less volatile forecasts.

We next examine whether the frequency of discovery revisions—our proxy for 'discovery skill'—can predict future analyst performance. We find that cumulative discovery revisions (henceforth CDR) at the beginning of the year is positively associated with future forecast accuracy. In addition, CDR is positively associated with timeliness, indicating that high CDR is associated with analysts who provide timelier processing of public information, and hence, analysts with low CDR are more likely to follow and use the information in high CDR analysts' forecasts. Thus, our findings further suggest that cross-sectional differences in accuracy and timeliness across analysts are positively associated with their engagement in discovery.

We complement the analysis by examining whether investors recognize differences in skill arising from the analyst's investment in discovery. Specifically, we examine investors' reaction to recommendation changes conditional on CDR as well as other analysts' characteristics that have been found to be associated with skill. The results indicate that investors' reaction to recommendation changes increases with CDR, and the relation is highly significant both statistically and economically. The reaction to

recommendation change by an analyst with an average CDR is greater by 5% relative to a zero CDR analyst.

This study provides several contributions to the literature. First, we provide in-depth analysis of the interplay between the discovery and interpretation roles of the analysts. We show that the two roles are substitute, and that discovery crucially depends on the information environment. The discovery role is particularly important when there are relatively fewer news related to the firm. In contrast, the supply of discovery revisions is low for firms with rich information environment. Second, using discovery revisions as a proxy for private information, we show that private information is associated with lower equity-return volatility in general and around earnings announcement date, and with lower difference between the two volatilities. These findings suggest that private information derived via discovery revisions is associated with greater price efficiency— the informativeness of equity prices increases with private information. Third, we show that differences in analysts' ability to discover private information explain cross-sectional differences in forecast accuracy, timeliness, and investor reaction to recommendations. In particular, analysts that provide more discovery revisions also provide more accurate and timely forecasts, and recommendation changes by these analysts elicit greater (in absolute value) market reaction. The latter result implies that investors who are clients of analysts with high CDR may achieve higher profits by trading prior to the publicly announced recommendation of these analysts. Clients of brokerages have early access to stock recommendations issued by the brokerage (Kim et al. 1997) and are able to trade on the information and generate abnormal returns (Green 2006; Irvine et al. 2007).

The remainder of the paper proceeds as follows. In Section 2 we provide a literature review and develop the hypotheses. Section 3 describes the data and variables.

Section 4 provides the empirical results. Section 5 concludes.

II. Hypotheses Development

One useful way to better understand the operation of analysts and to evaluate their contribution to capital markets is to separate between the two main roles of analysts—interpretation and discovery (e.g., Chen et al. 2010; Livnat and Zhang 2012; Rubin et al. 2016). In the interpretation role, analysts use their expertise and knowledge to analyze public information and to transform the analysis into forecast and/or recommendation revision. In the discovery role, analysts gain access to private information through various channels, such as private interactions with managers (Soltes 2014), corporate site visits (Cheng et al. 2015), or information collection from sources that are not directly linked to the company (e.g., suppliers, customers). Analysts then analyze the information and transform the analysis to forecast or recommendation revision.

This definition of the two roles allows one to identify the impetus (i.e., interpretation or discovery) for the forecast revisions; that is, whether the forecast revision arises from interpretation information that is publicly available, such as information released by the company, or from private information acquired by the analyst. Put differently, following Livnat and Zhang (2012), Ivkovic and Jegadeesh (2004) and Chen et al. (2010), we assume that forecast revisions without recent public information are considered as discovery revisions reflecting primarily private information of the analyst. In a similar vein, we assume that revisions following unanticipated public information emanating directly from the company or information about the company from other news providers are likely to be associated with the interpretation role.

The evidence in the literature indicates that both types of revisions are informative. Livnat and Zhang (2012) examine market reaction around forecast revisions and find that

investors' reaction to revisions following corporate news is about 30% greater relative to forecast revisions classified as discovery revisions. Huang et al. (2016) find that investor reactions to both information roles are economically significant and incremental to the reaction to the conference call information and earnings news, and that the value of each information role increases with the length of the discussion.

Huang et al. (2016) further examine the relation between the two roles. They find that analysts engage in more discovery when managers are more likely to withhold information, and provide more effort in interpreting information when the cost of processing management disclosure is higher. Building on Huang et al. (2016), we argue that a major determinant of the demand and supply of the two roles is the information environment of the firm. In particular, the interpretation role depends primarily on the amount of public information directly related to the firm. Firms, with greater amount of news (i.e., greater number of corporate filings—financial reports and 8-K reports) and greater number of other news directly related to the company (e.g., press articles) require more interpretation; hence, the demand (and supply) of interpretation revisions is likely to be greater. To the extent that public and private information are substitutes, then the greater the amount of public news related to the company the lower is the demand for private information and the lower is the likelihood of informative private information, and as a result, the lower is the likelihood that analysts would provide discovery revisions. However, if the two sources of information are complements, then one should not observe a negative relation between the two types of revisions. The complementary relation can arise especially in situations where discovery revisions are based on information that is not directly related to the company, such as financial reports of competitors or economy- and industry-wide related information.[4] Hence,

[4] Firms are required to report material information directly related to their operations; there is no legal requirement for firms to disclose industry or macro related information. Hence, it is reasonable to assume that information disclosed by the firm does not necessarily pre-empt industry or macro level information,

our first set of hypotheses:

H1a: Discovery revisions are informative

H1b: The likelihood of Discovery revisions is negatively associated with the amount of publicly available news directly related to the company

H1c Investors' reaction to Discovery revisions decreases with the amount of publicly available news directly related to the company

Our next hypothesis focuses on the relation between discovery revisions and prices, and in particular, the relation between private information and prices. The literature typically uses indirect proxies of private information in the form of volatility of returns. For example, French and Roll (1986) infer the likelihood of private information based on equity return volatility, Easley et al. (2002) use the probability of private informed trading (PIN measure) as a proxy for private information, and Barron et al. (1998) use a model based on forecast dispersion and error to shed light on analysts' underlying information sources. Under the assumption that forecast revisions not associated with public news represent the outcome (in the form of forecast revision) of private information acquired and analyzed by analysts, one can examine the association between a direct proxy of private information and prices, and, in particular, the association between private information and price efficiency. In other words, we are interested in examining whether the extent of private information is associated with more efficient prices—that is, whether prices reflect more value-relevant information. Since we are not concerned about the sign of the news, we follow Griffin et al. (2011) and focus on volatility around earnings announcements relative to a benchmark period (i.e., abnormal volatility) and volatility in general.

The relation between private information and volatility can be both positive and negative. On the one hand, the flow of private information induces trading resulting in

and furthermore, the latter sources of information can assist analysts in interpreting company related information.

greater volatility (French and Roll 1986). On the other hand, return variability arises from high uncertainty about future cash flows, and analysts' private information delivered via discovery revision can reduce information asymmetry and, therefore, the relation can be negative. Notwithstanding the ex-ante ambiguous relation between private information and return variability in general, the relation between private information and volatility around earnings announcements is expected to be negative. To the extent that discovery revisions are informative, they tend to preempt earnings news, thereby resulting in lower volatility. Hence, our next set of hypotheses:

H2a: Private information is associated with equity return volatility

H2b: Private information is negatively associated with equity return volatility during earnings announcements dates

H2c: Private information is negatively associated with forecast error

Our next hypotheses relate the production of private information through discovery revisions to analysts' skill. Rubin et al. (2016) measure analysts' interpretation skill based on the reaction of analysts to unanticipated information. They show that high interpretation skill is associated with greater forecast accuracy and timeliness. In addition, they also find that interpretation skill is associated with heightened market reaction to recommendation revisions. Given that analysts operation is determined by both her ability to interpret information and to discover information, we hypothesize that engagement in information discovery is positively associated with skill—analysts who engage in more information discovery are likely to be more skillful. Further, if discovery is indeed associated with skill, then—to the extent that the market recognizes this relation—investors react more strongly to recommendation changes made by analysts with high discovery. Hence,

H3a: Analysts with high discovery revisions provide more accurate and timely forecasts

H3b: Market reaction is higher to recommendation changes by analysts with high discovery revisions

III. Data

The main data in this study consists of firm stock returns, financial statement data, earnings forecast data, and news articles. The sample period is from 2005 through 2015. We choose 2005 as the starting year because the SEC mandated a major change to Form 8-K that became effective on August 23, 2004. The change significantly expanded the number of items (i.e., scope of material events) that must be reported via an 8-K filing, and hence, has resulted in a different form.

Daily returns, market capitalizations, and volume are from CRSP. Because we desire to capture the effects of information release on stock prices, we require stocks to be actively traded; all stocks are required to have price changes around at least one quarterly earnings announcement during the fiscal year and during the 10-day period before and after the quarterly earnings announcement. In addition, we eliminate small firms with market value of equity less than $10 million dollars.

Financial statement data are from Compustat. We require non-missing data for profitability (income before extraordinary items scaled by total assets), leverage (sum of short- and long-term debt scaled by total asset), book-to-market ratio (common equity scaled by market value of equity at fiscal year-end). Analysts forecast data are from the I/B/E/S detail dataset. We use the sample of annual EPS estimates and earnings announcements.

The news data are from two sources. We obtain data on SEC filings from SEC Analytics, which includes the filing date as well as the content of all filings submitted to the SEC by public companies. We restrict the sample to filings or amendments of each of the quarterly and annual financial reports (10-Q and 10-K, respectively), material corporate events (Form 8-K), and the proxy statement (DEF 14A). In addition, for the sample of 8-K

forms, we obtain data on the items disclosed. The list of items disclosed within each 8-K reports allows us to separate the 8-K forms into earnings and non-earnings related reports. The second source of news data is the Key Development Data, which is a comprehensive data of firm-related news. The data includes 149 categories of news items collected from over 20,000 news sources, regulatory filings, call transcripts, investor presentations, and company websites.

Table 1 provides firm-year descriptive statistics for the main variables used in the analysis. All variables used in this study are defined in Appendix I. Mean (median) equity value is $4.80 billion ($726 million); mean return on assets is close to zero, but the median is 2.8% and the proportion of loss years is close to 0.26; mean equity return volatility is 2.9%; and mean (median) book-to-market is 1.25 (0.55). Book leverage is on average 20%. The mean number of analysts following a firm in a given year is 9.9, and on average there are close to 41 forecast revisions during the year. Mean equity-return volatility around earnings dates is 0.03, and the mean difference relative to non-earnings dates is 0.012, indicating greater volatility around earnings dates.

IV. Results

4.1 Isolating Discovery Revisions

Following Rubin et al. (2016) and Livnat and Zhang (2012), we distinguish between the discovery and interpretation roles of analysts based on whether the revision is preceded by firm-related news and by the type of news. In particular, forecast revision that is not preceded by any firm-specific news or forecast revision by another analyst covering the firm (see below) is considered as a revision associated with the discovery role. This definition is quite intuitive as it is based on the basic premise that the absence of firm-related news prior to the revision suggests that the revision is induced by private information discovered by the

analyst.

To identify revisions associated with the interpretation role of analysts, we determine whether the forecast revision follows unanticipated corporate announcement. Forecast revision following an anticipated corporate event, such as the earnings announcement, is potentially affected by the analyst's ability to predict the news. Consequently, the reaction to anticipated news is likely affected by both the discovery and interpretation roles of the analyst, making it difficult to determine the role to which the revision is related. In contrast, unanticipated announcements by definition cannot be predicted, and therefore, the reaction to such announcements depends only on the analyst's ability to interpret the information.

Hence, to facilitate the analysis, we classify the news data for anticipated and unanticipated news. Anticipated news relates to the earnings of the company. Earnings are reported on a quarterly basis, and most companies announce in advance the exact date and time of the earnings announcement; thus, market participants anticipate the earnings reports. One of the analysts' main tasks is to predict earnings news ahead of its arrival; therefore, forecast revision (or lack thereof) following earnings news is indicative of both the extent of the earnings news and the analysts' ability to predict the news in advance—combining the analysts' discovery and interpretation roles. All other 8-K reports are defined as unanticipated news because these 8-K reports depend on the occurrence of events that analysts could not have predicted in advance. In contrast to anticipated news, the forecast revision or lack thereof following unanticipated reports is indicative only of analysts' ability to interpret the information—not of their discovery ability.

We define reaction to anticipated news as forecast revision within a window starting one day prior to and three days after the date of the following reports (henceforth, Reaction Window): 10-K, 10-Q, 8-K reports comprising of Item 2.02 (Results of Operations and Financial Condition), and the following Key Development Events—28 (Announcement of

Earnings) and 48 (Earnings Calls). Revisions within the Reaction Window of all other news (i.e., 8-K reports not including Item 2.02 or Key Development Events other than Events 28 and 48) are defined as revisions associated with the interpretation role of the analysts.

Finally, an analyst may provide a forecast revision following a forecast revision by another analyst. Shroff et al. (2014) show that such revisions are associated both with information interpretation and discovery, and hence, given the ambiguity, we treat revisions in the three days following revisions of other analysts as a separate category not associated with either the interpretation or discovery role of the analyst.

Taken together, we classify each forecast revision as follows: revisions within the Reaction Window of unanticipated news are labeled as Interpretation Revision; revisions within the Reaction Window of anticipated news are labeled as Earnings Revisions; revisions in the three days following a revision by other analysts are labeled as Other Analysts Revisions; all other revisions are labeled as Discovery Revision.

4.2 The Informativeness of Discovery Revisions

The sample for this analysis is based on the intersection of the I/B/E/S detailed file, news data, Compustat, and CRSP. The initial sample of forecasts includes 1,524,008. For each forecast we compute the revision (Forecast Revision) as the change in the EPS forecast relative to the most recent forecast scaled by share price at the beginning of the fiscal year. Requiring non-missing Forecast Revision reduces the sample to 1,147,393 forecasts. Merging the forecast data with Compustat and CRSP and requiring non-missing values of each of profitability, leverage, book-to-market ratio, standard deviation of daily return, and market value of equity greater than 10 million (all measured at the beginning of the fiscal year) reduces the sample to 1,052,917 forecast revisions.

Table 2, Panel A provides statistics related to the revision categories and their

characteristics. We observe that revisions following earnings are the most frequent—just over 51% of the total revisions, followed by interpretation revisions (28.6%). Discovery revisions account for 12.6% of the forecasts, and the remainder are revisions following other analysts revisions. The other columns provide the average of the forecast revision characteristics by revision type. We find that the absolute change in forecast is similar across revision types at around 1.7%. Although the change in forecast is similar, the reaction by investors is different in magnitude with reaction to earnings revisions is 6%. However, with the exception of discovery revision, little if any can be inferred from the reaction by investors because the revision window overlaps the news, and hence, the reaction by investors is likely related to both the news itself and the revision. Since discovery revisions are not preceded by news, one can infer that these revisions elicit on average a reaction of 3.5% in absolute value. The revisions also differ in terms of likelihood of improvement in the forecast error (i.e., if the revision resulted in lower forecast error relative to the previous forecast) and in the change in forecast error. Revisions following earnings are the most likely to result in improvement in forecast error (69.7%) and result in the greatest (in absolute value) decrease in forecast error (−7.4%). Discovery revisions, on the other hand, are less likely to result in improvement (62%), and they result in the lowest decrease in forecast error (−4.2%); nevertheless, these revisions are meaningful in the sense that they improve accuracy. Interpretation revisions are somewhat more meaningful relative to discovery revisions—the likelihood of improvement is 64%, and the change in forecast error is −6.2%.

Table 2, Panel B shows the properties of Discovery revisions conditioned on the amount of news. We partition the sample firms to High- or Low-news groups based on the median number of firm-related news (at the firm-year level) and present the mean forecast attributes of the discovery forecasts. The high (low) news group have on average 52 (26)

news items—financial reports, 8-K forms, and Key Development items—during the year. As expected, discovery revisions of low news firm-years entail greater economic impact. Specifically, the absolute change in the forecast is 1.9% vs. 1.6% for the high news group, the likelihood of forecast error is 63% (1.4% percentage points higher), and the change in forecast error is −4.6% as compared with −3.9% for the high news group. The greater economic impact of the discovery revisions also results in greater market impact: 1.9% vs. 1.6%. The differences in the variables across the two groups are also highly significant with *p*-values less than 1%. Hence, the univariate results support our conjecture that the informativeness and likelihood of discovery activities depends on firm-related news. Discovery revisions have more economic impact—greater news, greater likelihood of forecast error improvement, greater reduction in forecast error—and, consequently, elicit greater market reaction for companies with poor news environment.

Table 3 presents the regression results concerning the informativeness of discovery regions and the relation between the informativeness of the revisions and news environment. The sample for the analysis includes the discovery revisions (132,461 observations). The regressions include firm and year fixed effects, and the standard errors are clustered at the firm level. The dependent variable is the market-adjusted equity return in the three days centered on the discovery revision date. The main variable of interest is the forecast revision, measured as the change in EPS forecast scaled by beginning of the year price per share. The control variables include size, equity return volatility, leverage, profitability, book-to-market ratio, and the number of days from the date of the revision to fiscal year-end. Consistent with the evidence in Livnat and Zhang (2002), the first column shows that the coefficient on the change in forecast variable is positive and significant (*p*-value < 0.01), indicating that discovery revisions are informative and that investor reaction increases with the extent of the news provided in the revision. The second column replicates the regression in the first

column adding the log of total news and an interaction variable of the forecast revision and log news count to the independent variables.[5] This specification allows for testing whether investors' reaction to discovery revision depends on the amount of firm-related news. The coefficient on the forecast revision remains positive and significant (p-value < 0.01). However, the coefficient on the interaction variable is not significant, indicating that the association between the magnitude of the revision and investors' reaction is not mediated by the amount of news.

Taken together, the evidence in Tables 2 and 3 suggests that the proportion of discovery revisions is around 13%. In addition, discovery revisions are informative as they elicit significant market reaction. Although the univariate evidence indicates that the informativeness of discovery revisions depends on the richness of the news environment, regression results indicate that the informativeness of discovery revisions does not change with information environment.

4.3 The Determinants of the Discovery Role and the relation to the Interpretation Role

Having established the informativeness of the discovery revisions, we turn to examining the determinants of discovery revisions – primarily the relation between discovery and richness of news environment, and the relation between discovery and interpretation revisions.

Since the following analysis is conducted at the firm-year level, we measure the extent of discovery revisions as the total number of discovery revisions by the total number of forecast revisions during the year. We label this variable as the Discovery Ratio. We similarly compute the extent of interpretation revisions (Interpretation Ratio), and the

[5] The correlation between the interaction variable and forecast revision is very high (0.98). Hence, to alleviate concerns of multicollinearity, we demean the forecast revision and log-news count, and the interaction variable is based on the demeaned variables. The table shows the estimation results using the demeaned variables.

proportion of revisions following earnings news (Earnings Revisions Ratio). Hence, one way to interpret the Discovery Ratio is the proportion of private information relative to total information (private and public information) incorporated in expected earnings.

Table 4, Panel A provides descriptive statistics related to analysts' activity as well as information environment for quintiles formed on the basis of the Discovery Ratio. The results clearly indicate that the Discovery Ratio is inversely related to news count. We observe that the number of news items decreases monotonically with the Discovery Ratio. The number of news items for the lowest quintile is 57, whereas for the highest quintile the number is 28.5. Hence, the extent of private information greatly depends on the amount of news; the demand (and supply) for private information increases the less transparent is the news environment. Further, while we observe that earnings-related news decreases across the quintiles (from 8 earnings-related news in the lowest quintile to 6 in the highest quintile), the main reason for the decrease in news is the decrease in unanticipated news. The number of unanticipated news items decreases from 49 in the first quintile to 22 in the highest quintile. The monotonic decrease in the number of earnings and unexpected news items across quintiles is reflected in the monotonic decrease in the Earnings Revision Ratio and Interpretation Ratio, respectively.

Interestingly, while for the first 4 quintiles, the majority of the forecast revisions are related to earnings news, in quintile 5 almost 50% of the revisions are related to Discovery Revisions. The Panel also shows that the number of analysts and forecast frequency decrease across quintiles. One possible explanation is the decrease in news count across quintiles. Intuitively, the greater the amount of news the greater is the demand for interpretation and, hence, the greater the number of analysts and forecast frequency.

Table 4, Panel B presents descriptive statistics related to firm characteristics across Discovery Ratio quintiles. We observe a monotonic negative relation between Discovery

Ratio and firm size; mean market-value of equity for the lowest (highest) ratio is $11B ($1.2B). The negative relation between size and discovery is explained by information environment—the amount of news is increasing with firm size, and hence, for large firms the main role of analysts is information interpretation. For smaller firms, however, the main role of analysts is information discovery as there is less news to interpret. The profitability and R&D intensity columns indicate that there is no apparent linear relation between profitability and the Disclosure Ratio. We examine the relation between the Discovery Ratio and R&D intensity because of the lower information content of the financial reports for firms with large investments in R&D activities (Lev and Zarowin 1999). Similarly, we do not observe linear relation between firm risk (as proxied by equity return volatility) and the Discovery Ratio, although firms in the highest Disclosure Ratio have the highest operating risk.

The next columns look at the volatility measures. The volatility around the earnings dates indicates that it is the highest (lowers) for quintiles 1 (5), but the difference appears to be not economically meaningful. The benchmark volatility (volatility in the 10 days period before and after each earnings date window) is similar for the first 4 quintiles—around 0.18. In quintile 5, however, the mean is 0.2. The decreasing (increasing) volatility around earning dates (benchmark period) is reflected in differenced volatility, with monotonic decrease from quintile 2 through 5 from 0.14 to 0.09. Taken together, Panels A and B show that the disclosure ratio depends on the richness of the information environment. In addition, we observe that discovery revisions are particularly prevalent for smaller firms, and that discovery revisions are negatively associated with differenced volatility. The latter result appears to be driven primarily by lower volatility around earnings dates.

Table 4, Panel C presents mean of the analyst- and news-related variables by year. The statistics indicate several patterns. There is a general decline in discovery revisions from

0.21 in 2005 to 0.17 in 2014, which is likely explained by the increase in total news across the years, from 38 to 43, respectively. Although the average number of unexpected news items generally increase over the years (from 30 in 2005 to close to 36 in 2014), the proportion of interpretation revisions remain relatively flat. In contrast, while the proportion of earnings-related news decreased over the years, the proportion of revisions related to earnings news increased, especially in recent years. The increase in news is also reflected in the average number of analysts following as well as forecast frequency. The number of analysts increased from 8.8 in 2005 to 11 in recent years, and forecast frequency increased from 33.6 in 2005 to 45 in 2014.

Table 4, Panel D provides Pearson (Spearman) correlations among the main variables below (above) the diagonal. Consistent with the evidence in the prior panels, the Discovery Ratio is negatively correlated with the amount of news and the Interpretation Ratio, consistent with the two roles being substitute. In addition, the Discovery Ratio is negatively associated with volatility around earnings dates and differenced volatility.

Table 5, Panel A presents regressions results on the determinants of the Discovery Ratio and the relation between the discovery and interpretation activities of analysts at the firm-year level. The dependent variable in all regressions is the Discovery Ratio. Consistent with the univariate evidence, we observe that discovery revisions are negatively associated with news count, indicating that discovery is affected by the richness of the information environment around the firm; investors in firms with less news require more information, and analysts seem to react by providing more private information. In Column 2 we also include the Interpretation Ratio among the independent variables in order to examine the relation between the two roles. Similar to the univariate evidence we find that the coefficient on the Interpretation Ratio is negative and significant (p-value < 0.01), indicating that the two roles are substitutes—firms with high interpretation revisions have lower discovery

revisions, holding firm size and news count constant. To the extent that the Discovery Ratio and Interpretation Ratio are mechanically negatively related (given that both are measured as the respective revision scaled by total forecast frequency), we provide results with an alternative measure of the interpretation role. Specifically, we measure interpretation as the number of unexpected news that were followed by at least one forecast revision scaled by total unexpected news. This ratio provides the proportion of news that elicited reaction in the form of forecast revision by analysts, and hence, as the ratio increases more interpretation is provided by analysts. Untabulated results indicate the mean proportion of news interpreted is 0.16. This result is consistent with the evidence in Rubin et al. (2015), which show that on average analysts interpret about 15% of unanticipated 8-K reports. In addition, we also find that two measures of interpretation are positively correlated with Pearson correlation of 0.4. The regression results using the alternative interpretation measure are virtually identical, and the coefficient on the interpretation measure is negative and significant (p-value < 0.01).

We further examine the relation between the two roles by estimating the regression in Column (2) for quintiles formed on the basis of number of unanticipated news count. This analysis allows examining whether the relation between the two roles depends on the amount of news that is available for interpretation. One could argue that the negative relation between the roles is inherently determined by the amount of news—investor of companies that provide a lot of information have lower demand for private information and higher demand for information interpretation. Hence, by estimating the regressions by quintiles formed on the basis of unanticipated news count we isolate the impact of news available for interpretation. The results, however, indicate that the relation between the two roles is negative and highly significant (p-value < 0.01) across the quintiles, indicating that the negative relation between discovery and interpretation is not driven by news count per se. In other words, even when we hold the amount of news constant, high interpretation is

associated with low discovery and vice versa.

We compliment the analysis by examining the relation between the discovery and interpretation roles at the *analyst-firm-year* level. Specifically, the issue that we are interested in examining is whether analysts that provide discovery revisions also provide more (or less) interpretation revisions. While the evidence above suggests that more discovery revisions at the *firm-year* level are negatively associated with interpretation revisions, the relation at the *analyst-firm-year* is not clear ex-ante. On the one hand, the relation can be negative indicating that analysts who are good at providing discovery revisions are less good in providing interpretation. On the other hand, the relation can be positive - analysts that provide more discovery revisions are more diligent and skillful in general and therefore also provide more interpretation revisions.

To facilitate the analysis we need to aggregate the discovery and interpretation revisions at the *analyst-firm-year* level. For this purpose we measure discovery (interpretation) at the *analyst-firm-year* level as the total discovery (interpretation) revisions provided by analyst j covering firm i in year t scaled by the total number of discovery (interpretation) revisions for firm i in year t. We label the two variables as Analyst Discovery Ratio and Analyst Interpretation Ratio. Hence, the two ratios measure the proportion of discovery and interpretation revisions provided by each of the analysts covering the firm. Untabulated results show that the mean of the two ratios is 9%, but the median discovery (interpretation) ratio is 0 (3%). In fact, about 63% of the analysts did not provide even a single discovery revision, and 28% of the analysts did not provide a single discovery or interpretation revision.

Table 5, Panel B presents the regression results of Analyst Discovery Ratio on Analyst Interpretation Ratio controlling for analyst and firm characteristics. Prior research (e.g., Mikhail et al. 1997; Jacob et al. 1999; Duru and Reeb 2002; Clement 1999; Clement and Tse

2003, 2005; Malloy 2005; De Franco and Zhou 2009; Livnat and Zhang 2012) documents that analyst performance can be explained in part by analyst characteristics. Thus, following these studies, we control for the following characteristics: analyst's experience following the firm (Firm Experience), which is the number of years the analyst has covered the company as of year *t*; analyst's specialization (Number of Companies), which is the number of companies covered by the analyst in year *t*; resources of the brokerage house (Broker Size), which is the number of analysts employed by the brokerage firm employing the analyst in year *t*; and general experience (Number of Industries), which is the number of unique two-digit SICs of all companies followed by analyst *i* in the 12-month period prior to the forecast date.

We estimate the regressions using OLS with firm and year fixed effects in one specification, and with analyst and year fixed effect in another. Given that the dependent variable is truncated at zero we also present results using Tobit with firm effects. The results indicate that the relation between discovery and interpretation at the analysts-firm-year level is positive and highly significant (p-value<0.01), implying that analysts who provide more discovery revisions also provide more interpretation revisions. In addition, we find that analysts with greater experience, employed by larger brokerages, and cover more companies provide more discovery revisions. In contrast, analysts who cover more industries provide less discovery revisions.

Taken together, the results in Tables 4 and 5 indicate that discovery revisions are negatively associated with the total news related to the firm and that the discovery and interpretation activities are negatively correlated, indicating that the two are substitutes, at the firm-year level. However, we find the two roles are positively related at the analyst-firm-year level. The latter result suggest that analysts who provide more discovery are likely to be more diligent and skillful, and hence, are able to better interpret information.

4.4 The Discovery Role of Analysts and Price Efficiency

We next examine the relation between discovery and price efficiency, focusing on the level of volatility of stock returns during earnings announcement window. Following Griffin et al. (2011), We measure abnormal volatility as the absolute value of stock's return in excess of the value weighed market return. In addition, we also measure differenced volatility as the difference between volatility during the earnings announcement window and the average abnormal volatility during the 10 days before and after the earnings announcement window. The choice of volatilities during these particular windows is intended to reduce endogeneity concerns. As suggested in Frankel et al. (2006), the relation between analysts activities and return variability in general is likely endogenous. Specifically, return variability arises from high uncertainty about future cash flows. Analysts' private information delivered via discovery revision can reduce information asymmetry and, therefore, discovery revisions are negatively correlated with return variability. However, return variability likely creates demand for discovery activities because the high uncertainty related to future cash flows suggests that investors can gain from information research; hence, firms with high information asymmetry potentially attract greater discovery activities.

While volatility in general and discovery are likely endogenous, the concern is less obvious as far as differenced volatility is concerned. Nevertheless, to control for the endogeneity of discovery revisions, we use two-stage least squares to estimate the relation between differences volatility and Discovery. In the first stage, we use the log of total news count and forecast frequency as exogenous instruments to the Discovery Ratio. We estimate the first and second stage regressions with firm and year fixed effects. Standard errors are corrected for firm clustering.

Table 6, Panel A presents the regression results. Column 1 shows that differenced volatility decreases with the predicted value of the Discovery Ratio (*p*-value < 0.01), indicating that the difference between equity volatility during earnings announcement window and the benchmark window are lower the greater is the discovery activity by analysts. Next we examine whether the results are attributed to volatility during the earnings announcement window, volatility during the benchmark period, or both. Columns (2) and (3) indicate that discovery is negatively related to volatility in both periods—firms with high discovery revisions have lower equity return volatility both during and outside the earnings announcement window. To further corroborate the negative association between discovery and equity return volatility, we also present results where the dependent variable is the standard deviation of daily returns during the year. The results are similar—equity return volatility is negatively associated with the proportion of discovery revisions. Hence, the results indicate that discovery revisions reduce information asymmetry and uncertainty related to future cash flows, thereby resulting in lower volatility of equity returns in general and around earnings announcements in particular.

To provide additional support for the negative relation between discovery and volatility around earnings announcements, we next examine the relation between discovery revisions and forecast error and dispersion. If discovery revisions enhance price efficiency then this implies that the earnings forecast is more informative – that is would be associated with lower forecast error. To facilitate the analysis, we follow extant literature and measure forecast error as actual EPS minus the consensus EPS, scaled by beginning of the year price per share. We measure the consensus as the mean EPS forecast, and the mean EPS forecast is computed based on the closest forecast to fiscal year-end. To eliminate the impact of staled forecasts we require that the forecast was provided no earlier than 90 days prior to fiscal year-end. We eliminate firm-years with less than 3 valid forecasts, and clear outliers

where the absolute forecast error is greater than 1.

Table 6, Panel B present the regression results. We observe that absolute forecast error and forecast dispersion decrease with the predicted value of the Discovery Ratio. Hence, these results imply that the EPS forecast informativeness – i.e. accuracy – increases with the extent of discovery revisions thereby resulting in lower forecast error and lower volatility in the forecast.[6]

4.5 Analysts' Discovery Frequency and Future Analyst Performance

The results thus far indicate that discovery revisions are informative. Hence, given the central role of discovery in analysts' activities, we next examine whether the extent of investment in discovery activities (i.e., discovery skill) is associated with overall skill—that is, whether it explains cross sectional differences in forecast attributes.

We measure analysts' discovery activities using their cumulative discovery revisions (CDR), which is measured at the firm-year-analyst level as the cumulative number of discovery revisions from the beginning of the sample or coverage starting-year (the latter of the two) through the beginning of the year. Similar to Rubin et al. (2015), we use cumulative amounts in computing this measure because discovery revisions are largely idiosyncratic as they may depend on the occurrence of events or release of information that are not directly related to the company but are likely to affect the company, such as information provided by competitors. In other words, an analyst that invests considerably in discovery may issue

[6] In an untabulated analysis we replicate the regressions in Panel A adding the predicted Interpretation Ratio to the independent variables. The results concerning the Discovery Ratio are very similar – we continue to find that volatilities during and outside the earnings announcement window and the difference in volatilities are negatively related to the predicted Discovery Ratio. The results related to the Interpretation Ratio are also very similar – volatilities are negatively associated with interpretation as well. Hence, the results indicate that analysts provide informative forecasts through interpretation of firm related information and by providing private information through discovery activities. Revisions resulting from interpretation and discovery reduce information asymmetry and uncertainty related to future cash flows thereby resulting in lower volatility of equity returns in general and around earnings announcements in particular. However, given that the predicted Interpretation and Discovery Ratios are obtained using the same exogenous variables, the correlation between the two variables is very high (90%) suggesting that multicollinearity is a concern.

several discovery revisions in one year and none in other years simply because there was no reason to issue a discovery forecast. Hence, ranking analysts based on the yearly discovery revisions would result in a noisy measure of discovery skill. Given how we construct CDR and the evidence that discovery depends on the information environment of the firm, it is evident that CDR is analyst-firm specific, and it can differ for the same analyst across the companies she covers. In other words, CDR does not measure the overall discovery skill of the analyst; rather, it provides a measure of discovery skill related to each company the analyst covers. We expect that the discovery skill of the analyst may vary across companies, much in the same way as forecast error varies across companies, because of differences in experience covering each company and differences in the various companies' information environments.

Similar to De Franco and Zhou (2009), our main measures of analysts' performance are accuracy and timeliness, which reflect analysts' ability to use and generate information. We measure accuracy as −1 times absolute forecast error (EPS forecast minus actual EPS, scaled by price at the beginning of the year) so that higher values of Accuracy are associated with more accurate forecasts. We expect a positive association between accuracy and CDR. We measure timeliness based on the number of days between the analyst's forecast and forecasts made by other analysts before and after the forecast. Specifically, for each forecast we compute Leading Days as the number of days between the forecast and the two most recent forecasts by any other analyst *following* the forecast date. Similarly, we compute Following Days as the number of days between the forecast and the two most recent forecasts by any other analyst issued *prior* to the forecast date. We compute Timeliness as the ratio of Leading Days to Following Days, multiplied by −1, so that a timelier forecast indicates that either the analyst reacts to the new information more quickly, or other analysts react to the news in the analyst's forecast. Hence, we expect to find a *positive* association

between Timeliness and CDR. We also use Boldness and Optimism as additional measures of performance. Boldness is computed as the absolute value of the difference between the forecast and the consensus forecast, scaled by the beginning-of-fiscal-year price per share, where the consensus forecast is the mean of all analysts' most recent forecasts issued during the 90-day period prior to the forecast date. This variable measures the analyst's confidence in providing a new forecast that deviates from the consensus. Similarly, Optimism is computed as the difference between the forecast and actual earnings, scaled by the beginning-of-fiscal-year price per share.

We examine the relation between analyst performance and CDR using the EPS forecast data we use above when examining the informativeness of Discovery revisions. Because we use CDR at the beginning of the year as an independent variable, we are not able to use year 2005 in the analysis. The total number of firm-year-analysts' forecasts with non-missing CDR is 728,434.

Table 7 presents the regression results. Since CDR is the *cumulative* reaction ratio, the analyst-firm-year observations are not independent. To address this issue, we estimate the regression on a monthly basis controlling for firm fixed effects, and present mean coefficients as in Fama and MacBeth (1973). We also control for variables that are correlated with forecast attributes. Specifically, we control for size, profitability, leverage, operating risk, and the book-to-market ratio. We correct the standard errors using the Newey and West (1987) adjustment, with 12 lags for serial dependence in the coefficients. This adjustment assumes that there is no correlation among coefficients that are more than 12 months apart.

The coefficient on CDR is positive in the Accuracy and Timeliness columns, indicating that analysts that engage more in discovery provide more accurate and timely forecasts in general. These findings are consistent with the conjecture that investment in

discovery (as reflected in greater number of discovery revisions) is associated with skill in general. The results of the Boldness and Optimism regressions suggest that analysts with high discovery tend to provide less bold but more optimistic forecasts.

Taken together, the results indicate that analysts with greater cumulative discovery revisions provide more timely and accurate forecasts in general. These results imply that cross sectional differences in forecast accuracy and timeliness can be explained by our proxy for discovery skill.

4.6 Analysts' Discovery Frequency and Investors' Reaction to Recommendation Changes

Because the cumulative discovery revisions (CDR) is correlated with analysts' performance, we can test whether cross-sectional differences in market reaction to recommendation changes is associated with our measure of discovery skill. Specifically, if investors internalize that analysts who engage in discovery are associated with better forecasting, then they should also react more strongly to recommendation changes made by these analysts.

We start with the entire sample of recommendation changes associated with firms in our sample period. To compute recommendation changes we require the analyst's current and previous recommendation. Merging the sample of recommendation changes with the sample of analysts with valid CDR at the beginning of the fiscal year results in a sample of 72,706 recommendation changes. We calculate investor reaction to recommendation changes using buy-and-hold cumulative abnormal returns in the three days centered on the recommendation announcement day. We estimate abnormal returns as value-weighted market adjusted returns.

To ensure that the investors' reaction is indeed attributed to the recommendation change and not to earnings news, we eliminate all recommendation changes that occurred

during the three-day trading period [0, 2] following earnings announcements. This further reduces our sample to 53,168 observations. Finally, we exclude from our sample all cases in which there is no variation in CDR across analysts in a given firm-year (14,883). Our final sample includes 38,285 observations.

An analyst's recommendation is an integer between 1 (strong buy) to 5 (strong sell), where a recommendation of 3 is a hold. We compute the recommendation change as the previous recommendation minus the current recommendation, so a positive recommendation change is an upgrade and a negative recommendation change is a downgrade. Although a recommendation change could potentially take on a value of between −4 and 4, in our sample 98.5% of recommendation changes are between −2 and 2; and the number of positive recommendations is approximately the same as negative ones.

Table 8 provides the results of the multivariate regressions. We estimate the regressions using OLS with firm and year fixed effects. The standard errors are adjusted for firm clustering. The control variables include the same firm and analyst characteristics as in the analysis above on the relation between CDR and forecast attributes.

The Upgrade column shows the regression of abnormal returns in the three days centered on the recommendation change date on CDR, controlling for the change in recommendation. As expected, the coefficient on the change in recommendation is positive and significant (p-value < 0.01). The coefficient on CDR is positive and significant (p-value = 0.027), indicating that investors' reaction to upgrades increases with CDR—that is, upgrades provided by high CDR analysts elicit greater market reaction. The Downgrades column replicates the regression, but the sample includes negative recommendation changes. The coefficient on the change in recommendation remains positive and significant (p-value < 0.01). The coefficient on CDR is negative and marginally significant (p-value = 0.102), indicating that downgrades also are also associated with more negative reaction. The control

variables are generally not significant, with the exception of brokerage—investors' reaction is heightened for recommendation changes by analysts employed by larger brokerages.

The All column shows the results when we combine the negative and positive changes. The coefficient of interest is the interaction term of change in recommendation and CDR. Because we are interested in the magnitude of the reaction to the recommendation change, a positive coefficient for this interaction term is interpreted as an increased reaction to the recommendation change of analysts with higher CDR. If control variables affect the magnitude of the reaction, they should enter the regression twice: once as a standalone variable and once interacted with the recommendation change which captures the marginal effect of the control variable on the return magnitude to the recommendation change (Hirshleifer et al. 2009; Michaely et al. 2014; Rubin et al. 2015). Failure to interact the control variable with the news variable (recommendation change) would provide an incorrect inference because the distribution of recommendation changes is on average zero; the effect of positive changes would cancel out the effect of negative changes. For example, consider market value of equity as a possible control variable. It is economically meaningless to expect that the market reaction to recommendation changes is more positive for larger firms (i.e., a positive coefficient on market value of equity), but it is economically meaningful to expect that the market reacts less to the analysts' recommendation changes for larger firms.

We find that the coefficient of Δ Rec × CDR is positive and significant at the 5% level. More importantly, the results indicate that CDR has an economic impact as well. Specifically, a one-unit recommendation change is associated with an increased reaction of 0.14% abnormal return for an analyst with average CDR. Because the mean CDR in the recommendation change sample is 0.75 and the coefficient on Δ Rec × log of CDR is 0.001, the reaction to a change in recommendation by the mean CDR analyst is greater by more

than 5% (i.e., 0.75 × 0.001/0.014) relative to an analyst with a zero CDR. Among the other control variables, we find that the reaction to recommendation change is greater for analysts employed by larger brokerages and analysts that cover more industries, and smaller for analysts who cover more companies and with greater experience.

V. Conclusions

In this paper we analyze the informativeness, determinants, and consequences of discovery revisions. Using the methodology of Livnat and Zhang (2012) and Rubin et al. (2015), we identify annual EPS forecast revisions that are associated with the discovery and interpretation roles of analysts.

We show that discovery and interpretation revisions are substitutes and that both are determined by the information environment. Analysts that follow firms with rich information environment engage primarily in interpretation and less in discovery, and the opposite holds for analysts that follow firms with fewer news count. Further, while discovery revisions are associated with equity returns, the importance of discovery for equity prices does not with the richness of the information environment.

We also find that discovery revisions (a proxy for private information incorporated in EPS forecast) are associated with more efficient stock price. Specifically, a greater proportion of discovery revisions is associated with reduced-differenced volatility as well as reduced volatility around earnings announcement dates and in general. These findings indicate that prices reflect more information the greater the number of discovery revisions, which is consistent with our findings that discovery revisions reduce information asymmetry. We also find that discovery revisions are associated with lower forecast error, implying that discovery revisions are associated with more accurate EPS forecast.

Given the central role of discovery in analysts' operation, we also examine whether analysts who engage in more discovery activities are more skillful in general. We observe that analysts who provide more discovery revisions also provide more accurate and timely forecasts in subsequent periods. Finally, we also find that investors react more strongly to recommendation changes from analysts who provide more discovery revisions.

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Appendix I – Variable Definition

Abnormal Return – market-adjusted equity return

Forecast Revision – change in EPS forecast (current EPS – Previous EPS) scaled by beginning of the year price per share

Accuracy – absolute value of forecast error, computed as the EPS forecast minus actual EPS, scaled by share price at the beginning of the year

Benchmark Volatility – mean absolute market adjusted equity returns during the 10 days before and after the earnings event windows

Boldness – the absolute value of the difference between the forecast and the consensus forecast scaled by the beginning of the year price per share; we compute the consensus forecast as the mean of all analysts' most recent forecasts issued during the 90-day period prior to the forecast date

Book-to-Market Ratio – ratio of Stockholders Common Equity (Compustat: CEQ) to Market Value of Equity

Brokerage – log of number of analysts employed by the brokerage during the year

Change in Forecast Error – forecast error of the current forecast minus the forecast error of the previous forecast

Companies– log of the number of companies (unique two-digits SIC) covered by the analyst during the year

Differenced Volatility – Equity Volatility around Earnings Dates minus Benchmark Volatility

Disclosure Ratio – ratio of total number of Discovery Revisions to Forecast Frequency during the year

Discovery Revision – forecast revision not following news or other analyst's revision

Earnings Revision – forecast revision within a window starting one day prior to and three days after the date of the following reports (Reaction Window): 10-K, 10-Q, 8-K reports comprising of Item 2.02 (Results of Operations and Financial Condition), and the following Key Development Events: 28 (Announcement of Earnings) and 48 (Earnings Calls)

Earnings Revision Ratio – ratio of total number of Earnings Revisions to Forecast Frequency during the year

Equity Return Volatility – standard deviation of daily equity return during the year

Equity Volatility around Earnings Dates - mean of absolute market adjusted equity returns in the three days surrounding the quarterly earnings announcement date (event windows)

Experience – log of the number of years the analyst has been covering the company

Forecast Error – EPS forecast minus actual EPS, scaled by price per share at the beginning of the fiscal year

Forecast Error Improvement – an indicator with 1 if the revision resulted in lower forecast error and zero otherwise

Forecast Frequency – total number of forecasts provided by analysts during the fiscal year

Horizon – log of number of days from the forecast date to fiscal year-end

Industries – log of the number of unique two-digits SIC covered by the analyst during the year;

Interpretation Ratio – ratio of total number of Interpretation Revisions to Forecast Frequency during the year

Interpretation Revision – forecast revision in the Reaction Window following unexpected news (News excluding earnings related news)

Interpreted News – number of unexpected news that were followed by at least one forecast revision scaled by total unexpected news

Leverage – sum of short- and long-term debt (Compustat: DLC+DLTT) scaled by total assets

Loss Year Indicator – indicator with 1 if Return on Assets is negative

Market Value of Equity – market value at fiscal year-end

Number of Analysts – number of analysts providing at least one forecast during the fiscal year

Optimism – the difference between the forecast and actual earnings scaled by the beginning of the year price per share

Other Analyst Revision – forecast revision in the three days following another analyst revision

Return on Assets – Income before Extraordinary Items (Compustat: IB) scaled by total assets at fiscal year-end (Compustat: AT)

Timeliness – the ratio of the number of days between the analyst forecast and the forecast by other analysts that precede and follow it. For each forecast we compute Leading Days as the number of days between the forecast and the two most recent forecasts by any other analyst preceding the forecast date. Following Days is the number of days between the forecast and the two most recent forecasts by any other analysts issued after the forecast date. We compute Timeliness as the ratio of Following Days to Leading Days.

Total Discovery Revisions – cumulative number of Discovery Revisions from the beginning of the sample or coverage starting-year (the latter of the two) through the beginning of the year.

Total Earnings News – number of news items related to the firm's earnings during the year; sum of total number of 10-Q, 10-K, 8-K reports including Item 2.02, and Key Development Events: 28 (Announcement of Earnings) and 48 (Earnings Calls)

Total News – number of news items related to the firm during the year; sum of total number of SEC filings (10-Q, 10-K, 8-K, Proxy statement) and Key Development news Items

Total Unanticipated News - Total News minus Total Earnings News

Table 1: Descriptive Statistics

	Mean	Standard Deviation	Q1	Median	Q3
Market Value of Equity	4,798	18,605	219	726	2,594
Return on Assets	−0.005	0.178	−0.002	0.028	0.070
Equity Return Volatility	0.029	0.015	0.018	0.025	0.036
Leverage	0.205	0.196	0.026	0.162	0.327
Loss Year Indicator	0.258	0.438	0.000	0.000	1.000
Book-to-Market	1.250	3.530	0.318	0.546	0.898
Number of Analysts	9.920	8.610	4.000	7.000	14.000
Forecast Frequency	40.8	45	11	26	53
Equity Volatility around Earnings Dates	0.030	0.017	0.017	0.026	0.038
Difference in Volatility	0.012	0.013	0.003	0.010	0.019

Notes: The table provides descriptive statistics of main variables used in the analysis. The sample consists of 35,266 firm-years observations. Variables definition appears in Appendix 1. We require non-missing values for each of the variables and market value of equity greater than 10 millions.

Table 2: Properties of Forecast Revision

Panel A: Properties of Forecast Revision by Type of Revisions

Forecast Revision Type	Proportion	Absolute Revision	Absolute Return	Forecast Error Improvement	Change in Forecast Error
Discovery	0.126	0.017	0.035	0.622	−0.042
Interpretation	0.286	0.017	0.045	0.641	−0.062
Earnings	0.514	0.018	0.060	0.697	−0.074
Other Analysts	0.074	0.015	0.038	0.643	−0.058

Panel B: Properties of Discovery Revisions Conditioned on Amount of News

News Rank	Total News	Absolute Revision	Absolute Return	Forecast Error Improvement	Change in Forecast Error
Low News	26	0.019	0.037	0.630	−0.046
High News	52	0.016	0.034	0.616	−0.039
Diff		0.003***	0.003***	0.014***	−0.007***

Notes: Table 2, Panel A provides the proportion of the various revision types and the mean of the revision properties by type of revision. The sample is based on 1,052,917 forecasts. Panel B presents the mean of the revision properties of Discovery Revisions, conditioned on the amount of news. Specifically, we partition the discovery revisions to High News and Low News groups based on the sample median of news count, and show the mean revision properties for each group. The sample is based on 132,461 discovery revisions.

Table 3: Investors Reaction and Properties of Discovery Revisions

	(1)	(2)
Constant	0.029***	0.026***
	(0.000)	(0.000)
Forecast Revision	0.022***	0.022***
	(0.000)	(0.000)
Log News Count		−0.002***
		(0.003)
Forecast Revision* Log News Count		-0.002
		(0.782)
Log Number of Days to Fiscal Year-End	0.000**	0.000**
	(0.012)	(0.012)
Log Market Value of Equity	−0.004***	−0.004***
	(0.000)	(0.000)
Equity Return Volatility	0.057**	0.058**
	(0.040)	(0.036)
Leverage	−0.006**	−0.005**
	(0.011)	(0.022)
Return on Assets	-0.004	−0.004
	(0.221)	(0.182)
Book-to-Market	−0.000	−0.000
	(0.773)	(0.888)
R-squared	0.004	0.004

Notes: Table 3 examines the informativeness of Discovery Revisions. The dependent variable is market adjusted equity return in the three days centered on the discovery revision date. The sample included 132,461 discovery revisions. The regressions are estimated using OLS with firm and year fixed effects. P-values are in parentheses. Standard errors are corrected for firm clustering. *, **, *** denotes significance level at the 10%, 5%, 1%, respectively. Column (1) shows regression of abnormal returns on the forecast revision and control variables. Column (2) replicates the regression in Column 1, adding the log of total news count and an interaction variable of log news count and the revision. To reduce the effect of multicollinearity, Log News Count and Forecast Revision are demeaned, and the interaction variable is based on the demeaned variables.

Table 4: Descriptive Statistics Discovery Ratio

Panel A: Discovery Ratio and News Environment

Discovery Ratio Quintiles	Discovery Ratio	Interpretation Ratio	Earnings Revisions Ratio	Total News	Total Earnings News	Total Unanticipated News	Number of Analysts	Forecast Frequency
1	0.023	0.287	0.671	57.100	8.040	49.000	11.600	49.200
2	0.092	0.244	0.620	45.700	8.320	37.400	14.100	60.700
3	0.147	0.224	0.578	39.100	7.810	31.300	11.400	47.000
4	0.227	0.207	0.514	34.300	7.260	27.100	8.250	32.700
5	0.495	0.158	0.310	28.500	6.170	22.400	4.020	13.700

Panel B: Discovery Ratio and Firm Characteristics

Discovery Ratio Quintile	Market Value of Equity	Return on Assets	R&D Intensity	Equity Return Volatility	Earnings Volatility	Benchmark Volatility	Differenced Volatility
1	11,020	-0.031	0.322	0.029	0.031	0.018	0.013
2	5,654	0.005	0.215	0.027	0.030	0.016	0.014
3	3,682	0.009	0.164	0.028	0.030	0.017	0.013
4	2,341	0.006	0.152	0.029	0.029	0.018	0.011
5	1,236	-0.015	0.177	0.031	0.029	0.020	0.090

Panel C: Discovery Ratio and News Environment by Year

	Discovery Ratio	Interpretation Ratio	Earnings Revisions Ratio	Total News	Total Earnings News	Total Unexpected News	Number of Analysts	Forecast Frequency
2005	0.211	0.249	0.507	37.800	7.810	30.000	8.770	33.600
2006	0.205	0.216	0.544	39.100	7.740	31.300	9.040	34.500
2007	0.195	0.216	0.554	38.600	7.580	31.000	9.200	35.400
2008	0.204	0.219	0.531	38.700	7.580	31.100	9.200	39.600
2009	0.230	0.208	0.520	37.600	7.620	30.000	9.140	40.000
2010	0.184	0.227	0.548	44.700	7.420	37.200	10.100	43.100
2011	0.176	0.234	0.546	46.200	7.450	38.800	10.900	46.300
2012	0.189	0.232	0.534	43.000	7.390	35.600	11.100	47.200
2013	0.171	0.221	0.563	42.400	7.340	35.100	11.100	46.200
2014	0.173	0.221	0.561	43.200	7.310	35.900	11.000	45.100

Panel D: Correlations among Main Variables

	1 Discovery Ratio	2 Interp. Ratio	3 Earnings Revisions Ratio	4 Total News	5 Total Earnings News	6 Total Unexp. News	7 Market Value of Equity	8 Return on Assets	9 R&D Intensity	10 Number of Analysts	11 Forecast Frequency	12 Earnings Volatility	13 Differenced Volatility
1		−0.19	−0.50	−0.41	−0.19	−0.37	−0.19	−0.01	0.04	−0.31	−0.30	−0.06	−0.14
2	−0.24		−0.61	0.42	−0.19	0.47	0.28	0.02	−0.07	0.23	0.27	−0.12	−0.09
3	−0.57	−0.62		−0.02	0.34	−0.10	−0.08	0.01	0.02	0.08	0.03	0.17	0.23
4	−0.32	0.41	−0.08		0.20	0.97	0.47	0.00	−0.12	0.47	0.47	−0.09	0.02
5	−0.17	−0.27	0.37	0.14		0.00	0.05	−0.01	−0.01	0.16	0.17	0.06	0.11
6	−0.30	0.46	−0.13	0.99	−0.01		0.47	0.00	−0.11	0.45	0.46	−0.10	0.00
7	−0.13	0.18	−0.06	0.49	0.04	0.49		0.40	−0.51	0.70	0.70	−0.39	−0.05
8	−0.02	0.01	−0.02	0.02	0.00	0.02	0.11		−0.32	0.24	0.24	−0.16	0.08
9	0.09	−0.05	−0.01	−0.12	0.00	−0.12	−0.18	−0.40		−0.23	−0.19	0.75	0.30
10	−0.35	0.17	0.05	0.45	0.13	0.43	0.41	0.18	−0.21		0.96	−0.09	0.13
11	−0.31	0.22	−0.05	0.42	0.13	0.41	0.41	0.17	−0.15	0.92		−0.07	0.14
12	−0.03	−0.11	0.14	−0.11	0.05	−0.12	−0.16	−0.22	0.70	−0.11	−0.10		0.79
13	−0.13	−0.10	0.21	−0.03	0.09	−0.04	−0.07	0.03	0.27	0.05	0.02	0.84	

Notes: Table 4 shows descriptive statistics related to the discovery ratio. Panel A (Panel B) shows mean of variables related news environment (firm characteristics) by quintiles formed on the basis of the discovery ratio. Panel C presents mean of main variables by year, and panel D shows Pearson (Spearman) correlation below (above) the diagonal.

Table 5: Determinants of Discovery Revisions and the Relation to the Interpretation Role

Panel A: Firm-Year Level Evidence

				Quintiles Formed on the Basis of Unexpected News				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	0.679***	0.567***	0.699***	0.761***	0.831***	0.821***	0.893***	0.701***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Interpretation Ratio		-0.260***						
		(0.000)						
Interpreted News			-0.245***	-0.303***	-0.236***	-0.184***	-0.208***	-0.157***
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log News Count	-0.100***	-0.053***	-0.111***	-0.110***	-0.142***	-0.159***	-0.165***	-0.122***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Market Value of Equity	-0.002	-0.001	-0.001	-0.014	-0.005	0.001	0.002	-0.001
	(0.337)	(0.642)	(0.534)	(0.123)	(0.429)	(0.889)	(0.672)	(0.830)
Return on Assets	0.022*	0.020*	0.022*	0.057	-0.029	0.026	0.006	0.008
	(0.063)	(0.070)	(0.056)	(0.217)	(0.497)	(0.287)	(0.831)	(0.637)
Loss Indicator	-0.003	-0.000	-0.001	-0.012	-0.012	-0.007	-0.002	0.007*
	(0.397)	(0.880)	(0.761)	(0.237)	(0.172)	(0.370)	(0.690)	(0.055)
Book-to-Market	-0.002	-0.001	-0.002	0.003	-0.002	0.001	-0.001	-0.002
	(0.120)	(0.373)	(0.131)	(0.431)	(0.568)	(0.753)	(0.753)	(0.243)
R&D Intensity	0.001	0.000	0.001	0.010	0.003	0.002	0.001	0.002
	(0.583)	(0.772)	(0.651)	(0.141)	(0.517)	(0.678)	(0.777)	(0.577)
Number of Analysts	-0.046***	-0.044***	-0.020***	0.003	-0.024**	-0.017*	-0.031***	-0.014**
	(0.000)	(0.000)	(0.000)	(0.790)	(0.015)	(0.066)	(0.003)	(0.039)
R-squared	0.059	0.130	0.080	0.056	0.049	0.047	0.063	0.104

Panel B: Analyst-Firm-Year Level Evidence

	(1) OLS	(3) OLS	(2) TOBIT
Constant	0.401***	0.363***	0.369***
	(0.000)	(0.000)	(0.000)
Analyst Interpretation Ratio	0.090***	0.073***	0.206***
	(0.000)	(0.000)	(0.000)
Experience	0.006***	0.012***	0.021***
	(0.000)	(0.000)	(0.000)
Brokerage	0.001**	-0.006***	0.003***
	(0.036)	(0.000)	(0.000)
Industries	-0.004***	-0.007**	-0.029***
	(0.006)	(0.013)	(0.000)
Companies	0.003***	0.016***	0.025***
	(0.008)	(0.000)	(0.000)
Log Market Value of Equity	0.002***	0.003***	0.004***
	(0.000)	(0.000)	(0.000)
Return on Assets	-0.001	-0.004	0.021*
	(0.709)	(0.492)	(0.056)
Loss Indicator	0.001	0.001	0.000
	(0.248)	(0.396)	(0.878)
Book-to-Market	0.001***	0.001***	0.006***
	(0.002)	(0.002)	(0.000)
R&D Intensity	0.000	0.000	-0.009***
	(0.940)	(0.854)	(0.000)
Log Number of Analysts	-0.129***	-0.114***	-0.231***
	(0.000)	(0.000)	(0.000)
Year Fixed Effects	Yes	Yes	Yes
Firm Fixed Effects	Yes	No	Yes
Analyst Fixed Effects	No	Yes	No
R-squared	0.033	0.104	

Notes: Table 5 examines the determinants of Discovery Revisions and the relation between the discovery and interpretation roles. Panel A shows regressions results at the firm-year level. The dependent variable is the Discovery Ratio. The sample includes 35,266 firm-years. The regressions are estimated using OLS with firm and year fixed effects. Panel B shows the regressions of Analyst Discovery Ratio on Analyst Interpretation Ratio and analysts and firm characteristics. The sample includes 249,229 analyst-firm-year observations. P-values are in parentheses. Standard errors are corrected for firm clustering. *, **, *** denotes significance level at the 10%, 5%, 1%, respectively.

Table 6: The Relation Between Equity Volatility and Analysts' Roles

Panel A: Equity Volatility and Discovery

	Differenced Volatility	Earnings Window Volatility	Benchmark Volatility	Daily Volatility
Constant	0.020***	0.066***	0.046***	0.068***
	(0.000)	(0.000)	(0.000)	(0.000)
Discovery Ratio	−0.006**	−0.020***	−0.014***	−0.025***
	(0.044)	(0.000)	(0.000)	(0.000)
Market Value of Equity	−0.001***	−0.005***	−0.004***	−0.006***
	(0.000)	(0.000)	(0.000)	(0.000)
Return on Assets	0.003***	0.003***	−0.000	0.002***
	(0.001)	(0.006)	(0.698)	(0.003)
Loss Indicator	0.001**	0.002***	0.002***	0.003***
	(0.033)	(0.000)	(0.000)	(0.000)
Book-to-Market	0.000	0.000	0.000	−0.000
	(0.946)	(0.797)	(0.495)	(0.534)
R&D Intensity	−0.000***	−0.000***	−0.000	−0.000
	(0.002)	(0.005)	(0.630)	(0.349)
R-squared	0.020	0.244	0.550	0.570

Panel B: Relation between Discovery Revisions and Forecast Error and Dispersion

	Forecast Error	Forecast Dispersion
Constant	0.123***	0.172**
	(0.000)	(0.019)
Discovery Ratio	-0.085***	-0.822***
	(0.000)	(0.000)
Market Value of Equity	-0.014***	0.007
	(0.000)	(0.395)
Return on Assets	-0.021***	-0.131**
	(0.005)	(0.014)
Loss Indicator	0.012***	0.072***
	(0.000)	(0.000)
Book-to-Market	0.004***	0.016***
	(0.000)	(0.002)
R&D Intensity	-0.003***	-0.021***
	(0.002)	(0.009)
Observations	23,101	23,101
R-squared	0.127	0.036

Table 6, Panel A examines the relation between equity volatility and the discovery role. Panel B examines the relation between each of forecast error and dispersion and the discovery role The regressions are estimated using two-stage two least squares. The first stage (not tabulated) includes the log of total news count and forecast frequency as exogenous variables. Both stages include firm and year fixed effects. Standard errors are corrected for firm clustering. P-values are in parentheses. *, **, *** denotes significance level at the 10%, 5%, 1%, respectively.

Table 7: Discovery Frequency and Analysts' Performance

	Accuracy	Timeliness	Boldness	Optimism
Constant	0.13***	−19.252***	−0.047**	0.005**
	(0.000)	(0.000)	(0.011)	(0.042)
Total Discovery Revisions	0.013***	0.805***	−0.006***	0.001***
	(0.001)	(0.000)	(0.001)	(0.000)
Horizon	−0.012	1.197***	0.000	0.000
	(0.186)	(0.007)	(0.910)	(0.417)
Experience	0.006	−0.664***	−0.002	0.000
	(0.515)	(0.000)	(0.615)	(0.315)
Brokerage	0.005***	−0.584***	−0.002***	0.000
	(0.000)	(0.000)	(0.000)	(0.197)
Industries	0.016**	−1.153***	−0.005**	0.000
	(0.013)	(0.000)	(0.027)	(0.587)
Companies	−0.023***	0.474***	0.009***	−0.001*
	(0.002)	(0.000)	(0.000)	(0.098)
Log Market Value of Equity	0.005**	1.176***	-0.002	0.000**
	(0.012)	(0.000)	(0.117)	(0.012)
Equity Return Volatility	−6.205***	77.554***	3.015***	−0.421***
	(0.000)	(0.000)	(0.000)	(0.000)
Leverage	−0.093***	1.379***	0.038***	−0.006***
	(0.000)	(0.000)	(0.001)	(0.003)
Return on Assets	+0.363***	1.952**	−0.188***	0.014***
	(0.000)	(0.018)	(0.000)	(0.005)
Book-to-Market	−0.008***	0.261***	0.005***	−0.001***
	(0.000)	(0.000)	(0.000)	(0.001)

The table provides analysis of the relation between the frequency of Discovery Revisions and performance measures controlling for analyst and firm characteristics. All explanatory variables are measured as of end of fiscal year *t*-1. We estimate the regression on a monthly basis and present mean coefficients. Standard errors are corrected for serial dependence using the Newey and West (1987) adjustment, with 12 lags for serial dependence in the coefficients. P-values are in parentheses. ***, **, and * denote two-tailed significance at the 1%, 5%, and 10% level, respectively.

Table 8: Reaction to Analysts Recommendation Change and Discovery Frequency

	Upgrades	Downgrades	All
Constant	−0.001	−0.070***	−0.036***
	(0.956)	(0.000)	(0.000)
Δ Rec	0.004***	0.004***	0.014***
	(0.000)	(0.000)	(0.000)
Total Discovery Revisions	0.002**	−0.001	0.001
	(0.027)	(0.102)	(0.322)
Δ Rec * Total Discovery Revisions			0.001**
			(0.010)
Experience	0.003**	−0.001	0.001
	(0.037)	(0.602)	(0.321)
Brokerage	0.003***	−0.003***	−0.000
	(0.000)	(0.000)	(0.916)
Industries	−0.001	0.002	0.000
	(0.461)	(0.259)	(0.659)
Companies	0.001	−0.002	−0.001
	(0.625)	(0.107)	(0.343)
Log Market Value of Equity	0.000	0.008***	0.004***
	(0.888)	(0.000)	(0.000)
Equity Return Volatility	0.244***	−0.039	0.106*
	(0.007)	(0.659)	(0.083)
Leverage	−0.009	−0.003	−0.005
	(0.268)	(0.660)	(0.351)
Return on Assets	−0.001	0.008	0.005
	(0.933)	(0.415)	(0.430)
Book-to-Market	−0.000	−0.000	−0.000
	(0.489)	(0.925)	(0.598)
Δ Rec * Experience			−0.001*
			(0.051)
Δ Rec * Brokerage			0.002***
			(0.000)
Δ Rec * Industries			0.002***
			(0.000)
Δ Rec * Companies			−0.001***
			(0.001)
Δ Rec * Log Market Value of Equity			−0.001***
			(0.000)
Δ Rec * Equity Return Volatility			0.269***
			(0.000)
Δ Rec * Leverage			−0.005***
			(0.001)
Δ Rec * Return on Assets			−0.012***
			(0.000)
Δ Rec * Book-to-Market			−0.001***
			(0.000)
Observations	18,249	18,477	36,726
R-squared	0.013	0.020	0.148

The table shows differences in investor reaction to recommendation change conditioned on analysts' CDR. The dependent variable is the market adjusted equity returns. Δ Rec is the

recommendation change; positive integer (negative integer) change implies an upgrade (downgrade). The regressions are estimated with firm and year fixed effects. The standard errors correct for firm level clustering. ***, **, and * denote two-tailed significance at the 1%, 5%, and 10% level, respectively. P-values are in parentheses.