Implied Volatility Skew and Firm-Level Tail Risk

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Abstract

This paper examines the relation between firm-level implied volatility skew and the likelihood of extreme negative events, or tail risk. I find that high volatility skew predicts negative jumps in short-window earnings announcement periods, as well as in longer periods during which there are no earnings announcements. The predictability in non-earnings announcement periods, however, does not relate to particular firm disclosures - volatility skew does not predict negative jumps around management earnings forecasts or dividend declarations. The results suggest that options market participants possess information about impending negative news, but (outside of earnings announcement periods) do not necessarily know how that news will be revealed to the market.

1. Introduction

Estimated volatilities extracted from observed options prices exhibit a curious pattern: when plotted against strike prices, the distribution resembles a smile or a smirk (Rubinstein 1994; Jackwerth and Rubinstein 1996). Implied volatility at extreme strike prices (e.g., out-of-the-money puts and calls) is higher than for at-the-money options (the smile), and implied volatility is higher for low strikes than for high strikes (the skew). This pattern is in stark contrast to the fundamental Black-Scholes assumption that expected volatility is independent of the option's strike price.

In this paper, I investigate how the shape of the implied volatility function (hereafter, IVF) relates to the distribution of firm-level returns. Existing research suggests that implied volatility patterns contain information about future stock price behavior, both at the index and the firm level. Examples of this research include Bates (1991), who shows that out-of-the-money index puts became especially expensive in the year leading up to the October 1987 crash; Doran et al. (2007), who show that the skew in index-level implied volatility distributions has information about market crashes; and Xing et al. (2008), who document that stocks with the steepest skews underperform stocks with less-pronounced skews over prolonged periods.

I extend this research to investigate whether firm-level IVFs convey information about future return distributions, focusing on whether highly-skewed IVFs predict a higher likelihood of significant stock price drops. In other words, do volatility skews indicate tail risk? I analyze the predictive ability of volatility skew in both earnings and non-earnings periods to better understand the types of news/events that implied volatility functions anticipate. Finally, I examine the characteristics of firms with highly-skewed implied volatilities to determine the types of firms for which perceived tail risk is greatest.

My analysis, based on quarterly earnings announcements from 1996-2008, yields the following results. First, firms with highly-skewed implied volatility functions are more likely to experience extreme negative jumps, both within and outside earnings announcement periods. Second, while volatility skew predicts tail risk in non-earnings periods *generally*, that predictive ability does not extend to specific non-earnings disclosure events; volatility skew does not predict extreme negative returns around management earnings forecasts or dividend declarations. Third, volatility skews are persistent and associated with firm fundamentals such as book-to-market values, leverage, and prior stock price history.

This study adds to the broad literature investigating the relation between option and equity markets. In particular, I provide evidence that volatility skew represents an *ex ante* measure of firm-level tail risk, and that option markets participants can accurately gauge which firms posses greater tail risk. Importantly, while the ability to assess tail risk extends beyond earnings announcements periods, the lack of predictive ability for specific disclosures like forecasts and dividend declarations reveals that options markets do not possess information about how that tail risk will manifest. The results are consistent with prior studies documenting that options markets convey substantial information about impending earnings announcements, but much less information about management forecasts outside of earnings announcement periods (Rogers et al. 2009).

This paper also adds to the literature on arbitrage risk. Prior studies have shown that idiosyncratic volatility deters sophisticated investors from eliminating arbitrage opportunities (Mendenhall 2004; Pontiff 2006; De Jong et al. 2009; Shleifer and Vishny 1997). Of particular relevance, Ali et al. (2003) show that the abnormal returns associated with high book-to-market firms are related to the degree of idiosyncratic risk of each firm. Ali et al. conclude that idiosyncratic volatility deters arbitrage activity. In this study, I show that book-to-market (among other firm characteristics) is positively associated with volatility skew. Thus, difficult-to-hedge tail risk may be a particular aspect of idiosyncratic volatility that prevents arbitrageurs from eliminating market mispricing.

Finally, this paper contributes to the nascent accounting literature analyzing return distributions to infer firm disclosure characteristics. For example, Ball and Shivakumar (2008) assess the information content of earnings announcements by measuring the proportion of annual information revealed at those announcements, and conclude that earnings announcements reveal only a modest amount of information to the market. Kothari et al. (2009) document asymmetric responses to good and bad news disclosures, and conclude the asymmetry reveals that managers, on average, delay the release of bad news. My results indicate that certain firms may inherently have greater tail risk, which implies an underlying distribution of news arrival that is non-normal and asymmetric. An implication is that researchers using return distributions to infer disclosure characteristics should carefully consider whether those return distributions actually reflect underlying economic characteristics, rather than disclosure practices.

This paper is organized as follows. Section 2 discusses related research and my empirical predictions. Section 3 describes the sample selection and provides some descriptive statistics for the data. Section 4 documents the primary empirical analysis, while Section 5 examines the determinants of volatility skew and discusses the relevance of volatility skew to recent accounting and disclosure research. Section 6 concludes.

2. Prior Research and Empirical Predictions

2.1. Implied Volatility Patterns

A central assumption of the Black-Scholes option pricing model is that the underlying stock's distribution has a single volatility for a given horizon. The implication is that the volatilities implicit in observed option prices will reflect the estimated volatility of the underlying stock.[1] For at least two decades, though, that assumption has been violated – implied volatilities vary systematically with option strike prices, even among options sharing a constant expiration (Rubinstein 1994). Out-of-the-money options have higher implied volatilities than at-the-money options, while low strike price options have higher volatilities than high strike price options. The departure from constant implied volatility has been observed in foreign currency and equity options both domestically and around the world (Hull 2006).

For index options, the smile in the IVF became especially pronounced after the October 1987 stock market crash (Bates 2000; Foresi and Wu 2005).[2,3] One explanation for the shape is that the underlying stock return distribution is non-normal (more specifically, leptokurtic and negatively skewed).[4] (The US equity market is consistent with such a distribution.) However, distributional characteristics do not completely explain the IVF shape. Ederington and Guan (2002) illustrate this by estimating profits from trading based on the Black-Scholes smile (i.e., buying "cheap" options near the bottom of the smile and selling "expensive" options at the top of the smile). While they find that this strategy's profits are not as large as the Black-Scholes

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[1] This is true even if the underlying stock has time-varying volatility. Because the underlying stock can only have a single (average) volatility for a given horizon, all options sharing that horizon (expiration) should be valued with the same assumed volatility.
[2] There is some evidence of a similar pattern prior to that date. Bates (1991) studies the behavior of options on S&P 500 futures prices prior to the 1987 stock market crash, finding an unusually high premium for out-of-the-money puts relative to out-of-the-money calls in the year prior to the crash, and concludes that the higher put prices reflected investors' fears of a crash.
[3] Although much of the early work focused on index-level implied volatility, a similar phenomenon exists for individual stock options, albeit less pronounced (Bakshi et al. 2003; Bollen and Whaley 2004).
[4] The change in the distribution's shape after 1987, then, would have been driven by investors revising their beliefs about the likelihood of large stock price drops following the 1987 crash.

model predicts (indicating the underlying distribution is not lognormal), the existence of non-zero profits suggests additional sources for the IVF's shape.

Other explanations relate to investor characteristics, rather than objective expectations of future returns. Bakshi et al. (2003) attribute index skews to risk aversion in addition to a fat-tailed underlying distribution. Bakshi and Kapadia (2003) conclude that option prices imply a negative volatility risk premium (i.e., investors pay a premium to hedge against downside volatility). Liu et al. (2005) analyze the equity premium when investors are not only risk averse, but also averse to rare event uncertainty. They calibrate their model with equity options and conclude that rare event uncertainty and risk aversion both contribute to the smirk in option volatilities.

Regardless of the origin of the skew, numerous studies document that the shape of the IVF contains information regarding future stock price movements, particularly with regard to earnings announcements. In the next sections, I discuss the distributional characteristics of earnings announcements and the relation between implied volatility and earnings announcement-related returns.

2.2. Earnings Announcement Patterns

An implied distribution of returns that is negatively skewed and fat-tailed is consistent with the properties of realized earnings surprises and earnings announcement returns. McNichols (1988) uses several measures of skewness to examine stock return distributions around earnings announcements and finds that returns are more negatively skewed during earnings announcement periods than in non-earnings periods.[5] Basu (1997) and Givoly and Hayn (2000) document a similar pattern for scaled earnings. Gu and Wu (2003) suggest that the negative skew in earnings, combined with analysts who may be forecasting median earnings, leads to the appearance of optimistic bias in analysts' forecasts.

Like earnings and earnings surprises, investor response to earnings surprises exhibits asymmetry, as well. Skinner and Sloan (2002) study earnings announcement responses for growth stocks and show significantly larger responses to negative surprises than to positive surprises. They conclude that investors in growth stocks are overoptimistic, and that the over optimism is corrected at earnings announcements, resulting in large downward revisions of expectations and sharp drops in stock price.

Given these patterns in earnings and the way investors respond to them, earnings announcements pose a risky period for investors. Several studies document a return premium that compensates investors for the extra risk borne during the earnings announcement period (Ball and Kothari 1991; Cohen et al. 2007). Moreover, idiosyncratic volatility at earnings announcements appears to prevent arbitrageurs from fully participating in profitable situations such as the post-earnings announcement drift (Mendenhall 2004; Mashruwala et al. 2006). Overall, it seems reasonable that fear of extreme stock price drops is especially strong immediately prior to earnings announcements.

2.3. Relation Between Earnings Announcements and Implied Volatility

Patell and Wolfson (1979, 1981) provide early evidence that implied volatilities increase as earnings announcements approach, and that the increases tend to be associated with the

[5] Although not the objective of her study, she conjectures that the result could be driven by short sale restrictions, variation in discretionary disclosure behavior between good and bad news, or different incentives to acquire private information when news is good or bad.

magnitude of the earnings surprise. Isakov and Perignon (2001) extend this research by comparing the behavior of implied volatility around earnings announcements for positive versus negative earnings surprises. More recently, Ni et al. (2008) show that non-market option demand predicts realized (non-directional) volatility around earnings announcements.

The Patell and Wolfson (1979, 1981) and Isakov and Perignon (2001) studies investigate the relation between implied volatility levels and average earnings announcement returns, focusing on only a single point on the implied volatility surface. Since then, researchers have begun to investigate how other features of the implied volatility function relate to earnings announcement characteristics.

Xing et al. (2008) study volatility skew and find that firms with high volatility skews underperform firms with low volatility skews over periods up to six months. Further, they find that future earnings surprises are larger (i.e., more positive) for firms with less-pronounced skews. They conclude that informed investors trade in options markets, leading to the presence of the skew, and that equity markets are slow in incorporating this information. So (2008) performs a similar analysis with option market asymmetries and concludes, based on abnormal returns, that equity markets do not fully incorporate the information contained in options characteristics. Finally Diavatopoulos et al. (2008) look at changes in implied volatilities and volatility skew prior to earnings announcements and draw similar conclusions.

While those studies provide information about how implied volatility relates to earnings period returns, they leave several questions unanswered. Because their focus is on average portfolio returns, they do not speak to the relation between firm-level IVFs and the *distribution* of earnings outcomes. Given that the volatility skew is often attributed to rare, but significant, events (i.e., tail risk), an analysis of whether skews predict those events seems natural. In addition, they say little about predictive ability of implied volatility patterns in non-earnings periods and the types of events that option market participants appear to anticipate outside of earnings announcements.

2.4. Implied Volatility in Non-Earnings Periods

Significant price drops occur in non-earnings periods as well as earnings periods; Lee and Mykland (2008) confirm this intuitive statement by studying high-frequency trading data for three individual firms and showing the majority of equity price jumps occur with unscheduled company-specific news events. Less clear is whether these large stock price drops are predicted by options market participants in non-earnings periods. On the one hand, skew seems to predict large price drops at the index level, which should be largely unaffected by the occurrence of earnings announcements for particular firms. In addition, Cao et al. (2005) document that call option volume is significantly higher in periods leading up to takeover announcements, indicating that earnings announcements are not the only events for which option markets appear to convey information.

On the other hand, option markets could be especially well informed about a particular scheduled event (perhaps due to private information acquisition), but may not be informed about periods in which major events (e.g., earnings announcements) are not anticipated. In fact, while Amin and Lee (1997) and Cao et al. (2005) document significant increases in option trading in the days prior to earnings announcements and takeovers , Cao et al. (2005) note that option volume is *not* informative about future stock returns in “normal” times. Similarly, in their study of management earnings forecasts, Rogers et al. (2009) document very little increase in at-the-money implied volatility prior to the forecast (especially compared to pre-earnings options behavior).

2.5. Empirical Predictions

This study examines the relation between volatility skew and tail risk from several aspects. First, I predict that firm-level volatility skew predicts extreme negative returns in earnings announcement periods. This continues the stream of literature discussed in Section 2.3 examining the interaction between options and equity markets. This prediction is similar in spirit to prior studies of skew and market crashes at the index level (Doran et al. 2007; Bates 1991), but the focus on individual firms' options allows me to control for variation in underlying firm characteristics (e.g., size and leverage) in a way that index-level studies have not. Moreover, as Garleanu et al. (2009) point out, both the shape of the IVF and the demand pattern is different for equity options than it is for index options, which makes it difficult to extend the conclusions drawn from index-level data to individual firms.

Second, I expect that volatility skew predicts extreme negative returns outside of earnings announcements. As noted earlier, little is known about the relation between options characteristics and tail risk in periods outside of earnings announcement periods. Again, the focus on firm-level information makes it possible to identify when options do and do not have material, anticipated events (e.g., earnings announcements) in the option horizon.

Third, I predict that volatility skew also predicts extreme negative returns around major corporate disclosures in the non-earnings window. I focus on stock returns around two particular disclosures: manager forecasts and dividend declarations. Kothari et al. (2009) analyze these two disclosures and conclude, based on asymmetric responses to good and bad news, that managers withhold bad news until it reaches a certain threshold.

The next section discusses the source of my data, how I measure volatility skew, and various features of the sample data.

3. Data and Descriptive Statistics

3.1. Sample Selection

Earnings announcement information is drawn from the I/B/E/S historical database. I retain announcements for which I/B/E/S reports both an actual earnings value and at least one analyst estimate for the fiscal period being reported. I further require market value, price, and return data on CRSP, and book value and assets on Compustat. Finally, I eliminate firms with stock prices less than $5 prior to the earnings announcement. This process results in 121,526 quarterly earnings announcements between 1996-2008.

I obtain options data from the OptionMetrics historical option prices database, which includes closing bid and ask prices, option volume, open interest, and the implied volatility and other option Greeks (e.g., delta, gamma, and vega) for puts and calls on the entire listed US equity market. For each earnings announcement, I obtain these variables on two dates: three trading days prior to the earnings announcement and three trading days following the earnings announcement (when the earnings information is assumed to have been processed by the market). I refer to the earlier date as the "pre-earnings" measurement date and the later date as the "post-earnings" measurement date.

Because I am interested in distinguishing between earnings announcement information and non-earnings announcement information, I retain only those options expiring after the current earnings announcement, but before the subsequent earnings announcement. As a result, the options measured at the pre-earnings date include the impending earnings announcement, but no other, in their horizon. The options measured at the post-earnings date include no earnings announcements in their horizon.

In order to eliminate implied volatilities that are likely to be measured with error, I delete the following observations: the option's bid-ask spread is negative or is greater than 50% of the midpoint of the bid and ask; the option has negative time value (option price is greater than the difference between the strike price and the closing price); the closing price of the stock is less than $5 per share. Finally, like Bollen and Whaley (2004), I exclude options with absolute deltas below 0.02 or above 0.98.

3.2. Descriptive Statistics

Descriptive statistics are provided in Tables 1 and 2. As shown in Table 1, there are 80,106 earnings announcements from 1996 to the 3rd quarter of 2008 for firms that had quoted options prior to the earnings announcements. This represents approximately 2/3 of earnings announcements with the required I/B/E/S, CRSP, and Compustat data.

I provide more detail about the types of options listed for these firms in Table 2. Following Bollen and Whaley (2004), I categorize options into five groups based on the option's delta, where delta can be thought of as a rough approximation of the probability of the option expiring in the money. The purpose of this characterization is to obtain a distribution of implied volatilities relative to the degree to which the option is in or out of the money.[6] I then average, for each earnings announcement, the implied volatilities for all the options in each category. At

[6] Grouping options based on the delta is similar to classifying options based on the ratio of strike/current stock price, but takes into account factors such as time to maturity, dividend yield, and underlying volatility that may differ across individual stocks.

each measurement date, an earnings announcement observation has up to five implied volatility measures, depending on the amount and type of options listed on the firm's stock prior to the earnings announcement.

Table 2, Panel A (taken from Bollen and Whaley 2004) shows the range of deltas for each category. Category 1 options are those options with the lowest strike prices, including both deep-out-of-the-money ("DOTM") puts and deep-in-the-money ("DITM") calls. Category 3 options are approximately at the money options, with deltas ranging from .375 to .625 in magnitude. Category 5 options are those with the highest prices, consisting of deep-in-the-money puts and deep-out-of-the-money calls.

The breakdown of option availability is presented in Panels B and C of Table 2. Panel B shows observations with listed options, while Panel C retains only those options with positive open interest immediately prior to the earnings announcement. Consistent with prior research, closer-to-the-money options (Categories 2, 3, and 4) are more commonly listed (and traded) than options with extreme strike prices (Categories 1 and 5). For the extreme categories, low strike price options (Category 1) are more common than high strike options (Category 5), which is consistent with high demand for buying low-probability downside protection. In other words, the asymmetry in deep-out-of-the-money option listings suggests investors demand these options as a form of insurance.[7] Few firms have listed options across the full spectrum of moneyness categories. Of the 80,106 earnings announcements with any listed options, only 22,533 (28%) have listed options in each of the five moneyness categories. Panel C shows that only 18% of the 77,663 observations have options with positive open interest in each category.

[7] Because every open option position has a long and short party, one could argue that option volume is driven by either the writer or the purchaser. However, Garleanu et al. (2009) analyze a dataset of daily option positions for both dealers and end-users and show that end-users (i.e., proprietary traders and broker customers) have large net positions in out-of-the-money puts. This suggests that the existence of options is driven by purchasers of out-of-the-money puts, perhaps reflecting "crashophobia" (Rubinstein 1994).

3.3. Firm-Level Implied Volatility Functions

I summarize the shape of firm-level IVFs in both a graphical and statistical manner. Figure 1 provides graphical representation, and shows the average implied volatility for all options in each moneyness category. The dashed line presents the average implied volatility across all options meeting the stated criteria, with a different number of observations in each category. The solid line presents the average implied volatility figures for only those observations with listed options in each of the 5 categories, made up of 22,533 observations in each category. While both lines demonstrate the familiar skew pattern, the solid line's skew is more pronounced and better reflects the average firm's implied volatility function.

The data underlying Figure 1 is presented in Table 3, Panels A and B. Focusing on the results in Panel B (observations with options in each of the 5 categories), the average at-the-money implied volatility is 0.480 and ranges from 0.329 at the 25^{th} percentile to 0.576 at the 75^{th} percentile. The mean implied volatilities for the next two central groups (Categories 2 and 4) are only 3.4% and -0.6% away, respectively. The two deep-out-of-the-money groups possess the largest values, with a mean of 0.575 for Category 1 (DOTM puts) and a mean of 0.536 for Category 5 (DOTM calls).

Following prior literature, I quantify skew based on the difference in implied volatility between Category 2 options and Category 3 options (Bollen and Whaley 2004; Garleanu et al. 2009; Xing et al. 2008). Specifically, I calculate skew as the difference between implied volatilities of out-of-the-money puts (i.e., a subset of Category 2 options) and at-the-money calls (i.e., a subset of Category 3 options). The rationale for this choice is that demand for out-of-the-money put options reflects expectations of large stock price drops, and that at-the-money calls serve as an appropriate benchmark for the firm's overall uncertainty.[8] Thus, this measure of skew potentially reflects the likelihood of large stock price drops in excess of what would be expected from the firm's at-the-money implied volatility.

Using this calculation, skew is available for 36,710 earnings announcements. Table 4 provides descriptive statistics for the firms/earnings announcements that make up this final sample. Not surprisingly, the requirement that firms have listed options results in a sample of large firms with high analyst following. The mean market value is $10.9 billion, and the mean analyst following is 11.2. (By comparison, the firm-quarters without listed options have a mean market value of only $608 million and mean analyst following of only 3.9.) The mean and median deflated earnings surprises are fairly small (0.01% and 0.04%, respectively), and the 3-day earnings announcement period return is slightly positive, with a mean value of 0.41%.

Skew, measured before the earnings announcement, has a mean (median) of 0.042 (0.035). (Recall that the mean implied volatility for Category 3 options is 0.506.) Approximately 86% of observations exhibit positive skewness (i.e., the out-of-the-money put options have greater implied volatility than the at-the-money call options). The degree of the skew varies substantially across observations, ranging from 0.014 at the 25th percentile to 0.062 at the 75th percentile.

In Panel B, I present further information regarding the distribution of earnings surprises and earnings announcement returns. These measures, similar to those used by McNichols (1988), characterize the symmetry of the tails of the distribution. Each measure reflects the magnitude of the left tail of the distribution in relation to the right tail of the distribution, with the

[8] Taking a similar approach, Xing et al. (2008), point out that at-the-money calls are an appropriate benchmark for implied volatility as they have the highest liquidity among all traded options.

measures progressively using a smaller part of each tail.[9] In all cases, the variables are negatively skewed, although the skewness is much more severe for the earnings surprises than the associated stock returns. For example, the left half of the earnings surprise distribution is 71% larger than the right half of the distribution, while the left half of the returns distribution is only 4% larger than the right half of the distribution. The difference in skewness between the earnings values and the returns is consistent with extreme earnings realizations having significant transitory components (Freeman and Tse 1992; Beaver et al. 1979).

4. Empirical Analysis

4.1. Predictability of Extreme Negative Earnings Announcement Returns

My first prediction is that implied volatility skew contains information about the likelihood of significant negative returns in the impending earnings announcement period. I define "significant negative return" observations as those earnings announcements where the firm's stock price declines by at least 10% over the 3-day period surrounding the announcement. While the definition of a significant negative return is clearly subjective, I base my definition on the nature of the out-of-the-money put options, as I describe next.

For out-of-the-money puts in the final sample, the stock price prior to the earnings announcement exceeded the options' strike price by a mean of 12.5%, with the excess ranging from 8.4% at the 25th percentile to 15.5% at the 75th percentile. Framing it differently, the out-of-the-money puts would be exactly at-the-money if stock prices declined by a mean of 11.1% (7.7% and 13.4% based on the 25th and 75th percentiles, respectively). Because option

[9] More precisely, each measure is calculated as the ratio of (X percentile – 1st percentile)/(99th percentile – Y percentile), where Y is equal to 100 – X. So the 50% tail comparison is calculated as (50th percentile – 1st percentile)/(99th percentile – 50th percentile), and the 5% tail comparison is calculated as (5th percentile – 1st percentile)/(99th percentile – 95th percentile).

purchasers only profit to the extent that options finish in the money, purchasers of out-of-the-money put options are effectively betting on declines of at least that amount. My definition of an extreme negative return seems reasonable in light of the types of returns anticipated/feared by options investors. (I also present results based on cutoffs of -15% and -20%.)

I test my prediction using a probit regression, with the dependent variable equal to 1 when earnings announcement returns are less than or equal to -10%, and 0 when earnings announcement returns are greater than -10%. The independent variables are defined as follows:

Skew:	The difference between out-of-the-money put option implied volatility and at-the-money call option implied volatility
ATM IV:	Implied volatility of at-the-money options
Log(Market Value):	Natural logarithm of market value of equity
Book-to-Market:	Ratio of book of equity to market value of equity
Debt-to-Assets:	Ratio of total debt to total assets
Historical Volatility:	Standard deviation of daily stock returns for the 90 days prior to the earnings announcement
Historical Return:	Firm stock return in 90 days prior to earnings announcement

Implied volatilities and market value are measured three trading days prior to the earnings announcement. Book value, total assets, and debt are measured the quarter prior to the earnings announcement quarter. The independent variables are winsorized at the 1% and 99% levels, and standard errors are clustered at the 2-digit SIC level.

The results of this regression are presented in Table 5, with each of the 3 columns showing results based on a different cutoff for “significant negative returns”. The variable of interest, *Skew*, is positively associated with the probability of experiencing a significant negative return at the 1% statistical level for all 3 cutoffs. This supports the prediction that firms with greater implied volatility skews are more likely to experience large stock price drops at the upcoming earnings announcement. To assess economic significance of this result, I grouped observations into quintiles based on the pre-earnings volatility skew and estimated their conditional probability of experiencing a significant drop (holding all other variables at their mean value). The probability of experiencing such a drop increases from 7.4% for firms in the lowest quintile to 9.4% for firms in the highest quintile.

Most of the remaining independent variables are associated with large stock price drops in unsurprising ways. Firms with greater levels of uncertainty (*ATM IV*) and greater historical volatility (*Historical Volatility*) are more likely to experience extreme stock price drops. Large firms (*Log(Market Value)*) and firms with high book-to-market values (*Book-to-Market*) are less likely to experience such drops, as are firms with better stock performance during the last quarter (*Historical Return*). Perhaps surprisingly, firms with greater leverage (*Debt-to-Assets*) are less likely to experience extreme negative returns, although this could be due to the endogenous relation between a firm's leverage choices and the stability of that firm. Overall, the regression results indicate that greater volatility skew predicts a higher likelihood of significant earnings-related stock price drops.

The observed relation between volatility skew and extreme earnings-period returns is consistent with extant literature documenting that options markets impound earnings-related information prior to the earnings event (e.g., Amin and Lee 1997; Ni et al. 2008; Xing et al. 2008). Less clear, though, is whether the volatility skew contains information regarding non-earnings events. The next section provides information related to this question.

4.2. Predictability of Extreme Negative Returns Outside of Earnings Periods

Using the process described earlier, I measure *Skew* three trading days after the firm's earnings announcement, including only those options expiring at least three trading days prior to the firm's subsequent earnings announcement. By construction, any information in implied volatility skew should relate to the immediate non-earnings announcement period and not to the potential for tail risk in future earnings announcement periods.

Table 6 provides some descriptive information about the change in *Skew*, as well as at-the-money implied volatility, following the earnings announcement. Prior studies have shown that implied volatility increases prior to scheduled events and decreases thereafter (e.g., Patell and Wolfson 1981; Ederington and Lee 1996; Rogers et al. 2009). The same phenomenon holds in my sample, for both the implied volatility and the volatility skew. However, the declines in volatility and volatility skew do not appear substantial.

At-the-money implied volatility declines by a mean of 0.023 for options with open interest, relative to a mean value of 0.528 for the same options prior to the earnings announcement. Volatility skews decline by a mean of 0.001 (calculated for options with open interest), relative to the mean volatility skew of 0.042 prior to the earnings announcement. Overall, a substantial majority of the pre-earnings skew persists to the non-earnings period, even when there are no earnings announcements in the option horizon. Given the persistence of the volatility skew, it seems plausible that the skew conveys information regarding returns in non-earnings periods.

I test this prediction using a probit regression similar to that described earlier. The two differences between this regression and the regression described in Table 5 are: 1) *Skew* is measured following the earnings announcement, and 2) the (binary) dependent variable indicates the occurrence of a significant negative return in the non-earnings period. I present the results of this regression in Panels A and B of Table 7. In Panel A, I categorize significant negative returns based on cumulative stock returns during the non-earnings period (measured three trading days after the current announcement to three trading days prior to the next announcement), effectively treating the entire non-earnings period as a single event. In Panel B, I categorize significant negative returns based on the occurrence of a single day stock price drop.

In both Panel A and Panel B, the coefficient on *Skew* is positive and significant, indicating that implied volatility continues to have information content even outside of earnings periods. As in the earnings-period regression, firms with high at-the-money implied volatility and high historical volatility are also more likely to experience significant negative returns. In terms of probabilities, firms in the lowest skew quintile have a 26.5% likelihood of experiencing a cumulative -10% return, while firms in the highest skew quintile have a 31.6% likelihood of experiencing a -10% cumulative return. For single-day returns, firms in the lowest quintile have a 16.7% probability of a -10% stock return, compared to a 19.1% probability for firms in the highest quintile.

The results are stronger when defining extreme returns on a cumulative basis, rather than a single-day basis, judged by the t-statistics in Panel A compared to Panel B. One interpretation of the difference between Panel A and Panel B is that options skews convey information about the likelihood of extreme bad news, but less information about how that news is disseminated. For example, options investors may correctly assess that significant bad news will be revealed without knowing whether the firm (or other party) will gradually disclose that information over time or at a single date.

4.3. Predictability of Extreme Negative Returns Around Management Forecasts and Dividend Declarations

To determine whether implied volatility functions reflect tail risk associated with particular events outside of earnings announcements, I examine two types of non-earnings announcement disclosures: management earnings forecasts and dividend declarations. Kothari et al. (2009) study these two events and argue that they represent voluntary firm disclosures where managers exhibit a tendency to leak good news over time, but withhold bad news until it reaches a certain threshold. An implication of their argument is that these events may expose investors to tail risk.

Like before, I perform a probit regression using the occurrence of a -10% 3-day event period return as the dependent variable, and use the same independent variables described in Section 4.2. The results of this regression are shown in Table 8. Panel A presents the results for management forecasts, while Panel B presents the results for dividend declarations.[10] In each case, returns are measured for the 3-day window surrounding the event.[11]

As shown in Panel A, *Skew* exhibits little ability to predict extreme negative forecast-related returns. The estimated coefficient is not statistically different from 0 and is, in fact, negative for all three definitions of an extreme negative return. In contrast, the level of at-the-money implied volatility continues to demonstrate predictive ability, as does size, book-to-market, and prior stock return. The same is true for extreme negative dividend-related returns: at-the-money implied volatility is strongly associated with large drops, while *Skew* is generally unrelated. The only exception is when defining an extreme negative drop as one in which the firm experiences a return of less or equal to -20%. For that definition, *Skew* is positively

[10] Because the forecasts and dividend declarations occur outside of earnings announcement periods, I avoid the empirical challenges associated with bundled disclosures that Rogers and Van Buskirk (2009) discuss.

[11] The results shown in Table 8 are based on the sample of firms that actually issued a forecast (Panel A) or declared a dividend (Panel B) in the non-earnings period. As a robustness check, I also performed the regression over the full post-earnings sample, coding the dependent variable as 0 if the firm did not issue a forecast/declare a dividend. The inferences are unchanged.

associated with tail risk, with a t-statistic of 2.91. (It should be noted that this is an extremely rare event. Moving from the lowest to the highest *Skew* quintile increases the probability of experiencing a -20% dividend-related stock price drop from 0.03% to 0.17%.)

The results in Table 7 are consistent with the conjecture made earlier. Volatility skews convey information about fundamental firm tail risk, but (outside of earnings announcements) do not incorporate the manner in which bad outcomes are likely to be revealed to the public. The results in Table 7 are also in accord with Kothari et al. (2009), who argue that bad news is not leaked to the market prior to major voluntary corporate announcements.

5. Additional Analysis – Characteristics of Firms with High Implied Volatility Skews

Considering that implied volatility skews are relatively unchanged following earnings announcements and continue to predict tail risk in non-earnings periods, it seems natural to investigate the firm characteristics associated with implied volatility skew. That is, do certain types of firms simply have more inherent tail risk? To answer this question, I regress *Skew* on several factors that are typically thought to represent some aspect of firm risk. The results of this regression are presented in Table 9.

The dependent variable in Table 9 is *Skew* measured three trading days following the earnings announcement. Compared to the pre-earnings announcement value, this measure of *Skew* is more likely to capture firm-level characteristics rather than event-specific characteristics. (Recall that there are no earnings announcements in the option horizons measured post-earnings announcement.) That being said, the untabulated results using pre-earnings *Skew* as a dependent variable are largely similar to those shown in Table 9.

The first column includes the independent variables from the prior regressions and shows that *Book-to-Market*, *Debt-to-Assets*, and *Historical Volatility* are all positively related to volatility skew at the 1% statistical level. The associations are not surprising, considering that these variables can be thought of as reflecting some level of firm risk or uncertainty. An interpretation is that high book-to-market firms, highly leveraged firms, and firms with volatile stock prices share a certain type of risk: a greater exposure to tail risk. *Historical Return* is negatively related to volatility skew, suggesting that better-performing firms face a lower perceived tail risk. Finally, size is not significantly associated with volatility skew.

The second column adds at-the-money implied volatility as an independent variable, and the results are unchanged, with one exception: the significance of *Historical Volatility* declines substantially (from a t-statistic of 7.27 to 1.82). Given the high correlation between historical and implied volatility, this is not a surprising effect. Finally, in the third column, I add a binary variable equal to 1 if the firm experienced a single day stock price drop of 10% or greater in the prior non-earnings period. A positive coefficient on this variable would suggest that prior extreme stock price drops cause investors to increase their assessment of tail risk, much as the 1987 stock market crash is assumed to have done so at the index level. At the firm level, though, this is not the case. Implied volatility skew is unrelated to the occurrence of a significant negative jump in the prior period.

Overall, the results from Table 9 indicate that volatility skew is associated with several firm characteristics that can intuitively be thought of as reflecting measures of firm risk. The fact that volatility skew appears to be a persistent firm characteristic is noteworthy in light of recent studies in the disclosure area. Specifically, Ball and Shivakumar (2008) and Kothari et al. (2009) examine properties of firms' return distributions to draw inferences about those firms' disclosures. Ball and Shivakumar assess the relative information content of earnings announcements based on the proportion of annual information provided at those announcements, while Kothari et al. evaluate asymmetric disclosure responses to infer whether managers appear to withhold bad news.

While this study addresses different research questions than the previously-mentioned papers, it raises an issue that should be considered by future researchers. Namely, it seems that certain types of firms are perceived to be more likely to experience extreme stock returns than other types of firms. The difference in expected return distributions could be due to the disclosure practices of those firms, but could also be due to the underlying economic characteristics of the firms. Researchers drawing inferences based on return distributions should carefully judge whether they are capturing disclosure practices *per se*, or whether they are identifying underlying economic differences, such as greater tail risk.

6. Conclusion

I study the relation between implied volatility skew and the likelihood of experiencing extreme negative returns, or tail risk. Using quarterly earnings announcements from 1996 through 2008, I show that firms with greater volatility skew are more likely to experience large earnings period stock price drops. Outside of earnings announcement periods (i.e., when options have no earnings announcements in their horizons) volatility skew continues to predict significant negative price jumps. However, the predictive ability is not associated with specific disclosure events like management earnings forecasts or dividend declarations.

Taken together, the results reveal that implied volatility patterns contain information about firm-level tail risk. Volatility skew reflects tail risk both within and outside earnings announcement periods, indicating that the information in options markets extends beyond the events documented in earlier research (i.e., earnings announcements and takeovers). However, while volatility skew predicts tail risk in non-earnings periods *generally*, it does not predict tail risk related to other specific disclosure events (i.e., management forecasts and dividend declarations). In other words, options markets appear to correctly judge the likelihood of a significant adverse event, but not the manner in which the news will be revealed.

My results also suggest that volatility skew is a firm characteristic and is associated with many factors typically thought to reflect firm risk (e.g., book-to-market, leverage, and historical volatility). The relation between book-to-market, volatility, and implied volatility skew is interesting in light of Ali et al. (2003), who argue that idiosyncratic volatility prevents sophisticated investors from eliminating market mispricing. It may be that tail risk is a specific aspect of volatility that deters investors from taking concentrated positions.

Finally, the firm-level nature of volatility skew raises questions about the ability to infer financial reporting qualities from observed stock return distributions. Certain firms appear to have greater exposure to extreme event risk as a function of their underlying economics. Because of this, researchers evaluating financial reporting characteristics based on observed return distributions should be sure to control for the underlying economic drivers of those return distributions.

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Figure 1 – Implied Volatility Across Moneyness Categories

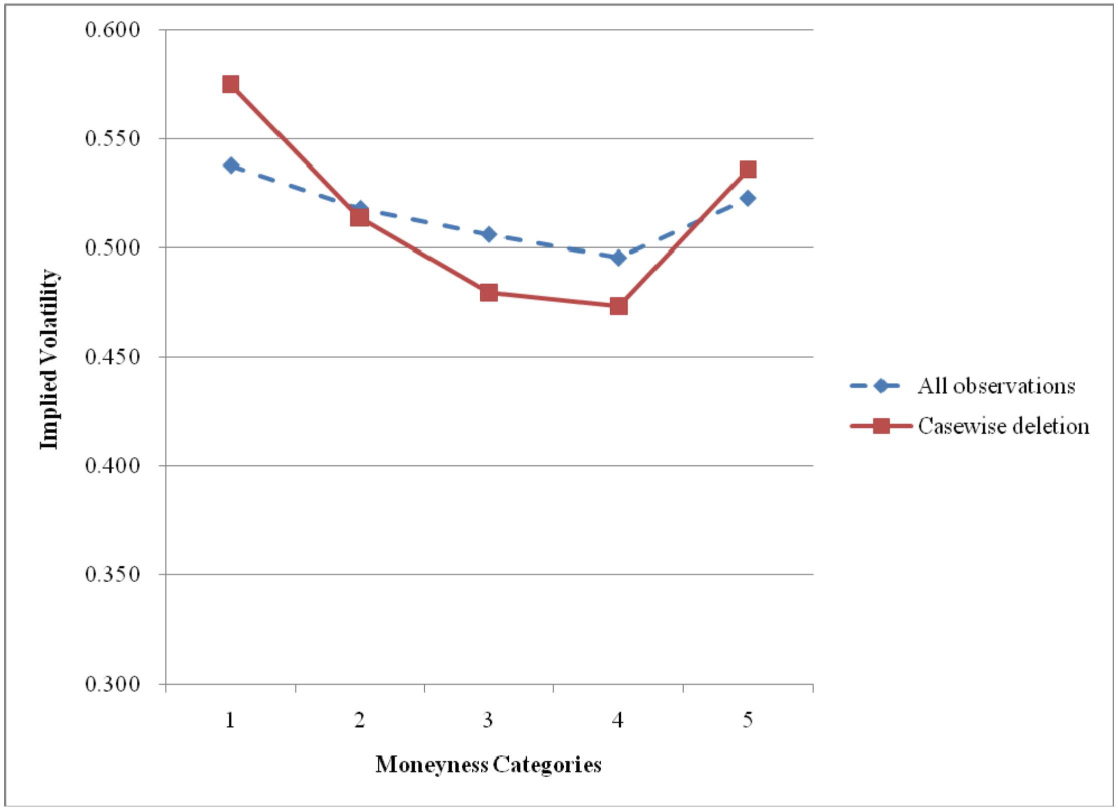

Figure 1 Notes:
This graph plots implied volatilities from US firms' listed options from 1996 through the third quarter of 2008. All listed options are obtained as of three trading days prior to each firm's earnings announcement and grouped into one of five moneyness categories. The moneyness categories are based on the option's delta, with Category 1 containing the lowest strike-price options and Category 5 containing the highest strike-price options. (The cutoffs for each category are detailed in Table 2, Panel A.) The vertical axis in Figure 1 is the average implied volatility across options in the particular moneyness category. The dashed line consists of all options for all sample firms, while the solid line includes only options for the 22,533 observations with options in each moneyness category.

Table 1 – Earnings Announcement Sample

Year	Earnings Announcements	Earnings Announcements with listed Options	Options Coverage
1996	8,031	4,173	52%
1997	11,124	6,330	57%
1998	10,836	6,957	64%
1999	10,044	6,907	69%
2000	7,852	5,001	64%
2001	7,501	5,109	68%
2002	8,184	5,795	71%
2003	8,628	5,864	68%
2004	9,647	6,440	67%
2005	10,136	6,718	66%
2006	10,829	7,209	67%
2007	10,782	7,681	71%
2008	7,932	5,922	75%
Total	121,526	80,106	66%

Table 1 Notes:
This table shows, by year of earnings announcement date, the composition of the earnings announcement sample. The left column includes all earnings announcements from 1996 through September 2008 with reported actual earnings and at least one analyst estimate on I/B/E/S, price and return data on CRSP, and equity and asset value on Compustat. The right column ("with listed options") requires observations to have listed options on OptionMetrics three trading days prior to the earnings announcement.

Table 2 – Sample Description - Options

Panel A – Moneyness Category Definitions (from Bollen and Whaley, 2004)

Category	Labels	Range
1	Deep in-the-money (DITM) call	$0.875 < \Delta_C \leq 0.98$
	Deep out-of-the-money (DOTM) put	$-0.125 < \Delta_P \leq -0.02$
2	In-the-money (ITM) call	$0.625 < \Delta_C \leq 0.875$
	Out-of-the-money (OTM) put	$-0.375 < \Delta_P \leq -0.125$
3	At-the-money (ATM) call	$0.375 < \Delta_C \leq 0.625$
	At-the-money (ATM) put	$-0.625 < \Delta_P \leq -0.375$
4	Out-of-the-money (OTM) call	$0.125 < \Delta_C \leq 0.375$
	In-the-money (ITM) put	$-0.875 < \Delta_P \leq -0.625$
5	Deep out-of-the-money (DOTM) call	$0.02 < \Delta_C \leq 0.125$
	Deep in-the-money (DITM) put	$-0.98 < \Delta_P \leq -0.875$

Panel B – Options Availability by Moneyness Category, all listed options

Year	Any listed option	Category 1 (Lowest Strike)	Category 2	Category 3 (At the Money)	Category 4	Category 5 (Highest Strike)	All Categories
1996	4,173	2,273	3,326	2,936	3,397	1,604	514
1997	6,330	4,026	5,419	4,733	5,343	2,452	967
1998	6,957	4,222	6,048	5,532	6,067	3,142	1,315
1999	6,907	4,117	6,137	5,626	6,032	2,825	1,284
2000	5,001	3,052	4,469	4,279	4,415	2,455	1,311
2001	5,109	3,587	4,676	4,259	4,641	3,011	1,912
2002	5,795	3,679	5,049	4,441	5,142	3,707	1,892
2003	5,864	4,226	5,069	3,973	4,908	3,493	1,759
2004	6,440	4,745	5,348	4,354	5,472	4,278	2,046
2005	6,718	4,820	5,452	4,261	5,481	4,381	1,971
2006	7,209	5,240	5,900	4,750	5,869	4,482	2,178
2007	7,681	5,666	6,388	5,212	6,469	5,017	2,693
2008	5,922	4,284	5,288	4,654	5,444	4,068	2,691
Total	80,106	53,937	68,569	59,010	68,680	44,915	22,533

Table 2, continued
Panel C – Options Availability by Moneyness Category, options with open interest

Year	Any listed option	Category 1 (Lowest Strike)	Category 2	Category 3 (At the Money)	Category 4	Category 5 (Highest Strike)	All Categories
1996	3,951	1,713	2,965	2,789	2,832	873	288
1997	6,096	3,119	4,819	4,438	4,404	1,225	442
1998	6,718	3,060	5,285	5,193	5,042	1,789	618
1999	6,680	3,205	5,416	5,312	5,133	1,639	708
2000	4,880	2,456	4,065	4,112	3,952	1,746	875
2001	4,988	2,647	4,225	4,046	4,023	1,943	1,097
2002	5,568	2,536	4,361	4,171	4,338	2,314	1,046
2003	5,717	3,233	4,645	3,784	4,055	1,978	982
2004	6,281	3,682	4,914	4,181	4,684	2,646	1,256
2005	6,505	3,814	5,027	4,105	4,806	2,907	1,302
2006	7,017	4,421	5,556	4,620	5,211	3,062	1,569
2007	7,488	4,798	6,027	5,071	5,885	3,346	1,901
2008	5,774	3,448	4,923	4,493	4,990	3,117	1,984
Total	77,663	42,132	62,228	56,315	59,355	28,585	14,068

Table 2 Notes:
Panel A describes the moneyness categories for each option, based on the option's delta, using the classification scheme from Bollen and Whaley (2004).

Panel B describes, for the earnings announcements in the sample, how many of the earnings announcements have options listed in each of the five moneyness categories. The last column in Panel B shows the number of earnings announcements with at least 1 option quoted in each of the five categories. Panel C is similar to Panel B, but includes only those options with positive open interest immediately prior to the earnings announcements.

Table 3 – Shape of Pre-Earnings Implied Volatility Function

Panel A – Raw Implied Volatility, all listed options

			Implied Volatility			
Moneyness Category		**N**	**Mean**	**Median**	**25th Percentile**	**75th Percentile**
DOTMP, DITMC	1	53,937	0.538	0.483	0.360	0.651
OTMP, ITMC	2	68,569	0.518	0.466	0.345	0.636
ATMP, ATMC	3	59,010	0.506	0.457	0.336	0.624
ITMP, OTMC	4	68,680	0.496	0.443	0.325	0.609
DITMP, DOTMC	5	44,915	0.523	0.459	0.339	0.633

Panel B – Implied Volatility, observations with options in each category

			Implied Volatility			
Moneyness Category		**N**	**Mean**	**Median**	**25th Percentile**	**75th Percentile**
DOTMP, DITMC	1	22,533	0.575	0.518	0.393	0.689
OTMP, ITMC	2	22,533	0.514	0.466	0.355	0.616
ATMP, ATMC	3	22,533	0.480	0.434	0.329	0.576
ITMP, OTMC	4	22,533	0.474	0.426	0.322	0.568
DITMP, DOTMC	5	22,533	0.536	0.474	0.353	0.646

Table 3 Notes:
Implied volatilities in this table are taken from all quoted options measured on a single date for each earnings announcement: three trading days prior to the earnings announcement. For each earnings announcement, the implied volatilities of all options in each moneyness category are averaged to get a single measure for that moneyness category. (Table 2, Panel A shows the cutoffs, based on the option's delta, for each moneyness category.)

Panel A includes information from all available options, while Panel B includes options for the 22,533 earnings announcements for which options were available in each moneyness category.

Table 4 – Univariate Statistics

Panel A – Firm/Earnings Announcement Characteristics

Variable	N	Mean	Median	25^{th} Percentile	75^{th} Percentile
Analyst Following	36,710	11.2	10.0	6.0	15.0
EAD 3-day Return	36,710	0.41%	0.34%	-4.17%	5.12%
Deflated Earnings Surprise	36,710	0.01%	0.04%	-0.01%	0.13%
Market Value	36,710	10,876	2,398	887	8,143
Book-to-Market	36,710	0.38	0.30	0.17	0.48
Debt-to-Assets	36,710	0.50	0.50	0.30	0.68
Skew	36,710	0.042	0.035	0.014	0.062

Panel B – Skewness of Earnings Surprises and Earnings Announcement Period Returns

Tail Measure	Left/Right Ratio
Earnings Surprise 5% Tails	207%
Earnings Surprise 10% Tails	194%
Earnings Surprise 25% Tails	179%
Earnings Surprise 50% Tails	171%
EAP Return 5% Tails	114%
EAP Return 10% Tails	110%
EAP Return 25% Tails	107%
EAP Return 50% Tails	104%

Table 4 Notes:

These descriptive statistics are based on earnings announcements from 1996 through the third quarter of 2008. Analyst following, earnings estimates, and market value are measured three trading days prior to the earnings announcement. Earnings surprises are calculated as reported quarterly earnings (per I/B/E/S) minus analyst estimates, deflated by the firm's stock price three trading days prior to the earnings announcement date. Stock returns are the buy-and-hold returns for the three-day period centered on the earnings announcement date. Book value, total debt, and total assets are measured the quarter prior to the current earnings announcement. Skew is equal to the implied volatility of out-of-the-money

(Category 2) puts minus the implied volatility of at-the-money (Category 3) calls, and is measured three trading days prior to the earnings announcement.

Panel B describes the symmetry of the earnings surprise and earnings announcement period (EAP) return distributions, showing a ratio of the left side of the distribution to the right side of the distribution. Each measure is calculated as the ratio of (X percentile – 1^{st} percentile)/(99^{th} percentile – Y percentile), where Y is equal to 100 – X.

Table 5 – Predictability of Extreme Earnings Announcement Returns

Independent Variables	Dependent Variable: Probability of experiencing earnings-related returns of: <=-10%	<=-15%	<=-20%
Skew	0.910 ***	0.816 ***	1.163 ***
	(5.86)	(5.27)	(5.84)
ATM IV	0.800 ***	0.924 ***	0.994 ***
	(6.88)	(9.46)	(9.37)
Log(Market Value)	-0.0650 ***	-0.0761 ***	-0.0757 ***
	(-7.98)	(-6.66)	(-5.88)
Book-to-Market	-0.128 ***	-0.0857	-0.109 *
	(-2.94)	(-1.54)	(-1.94)
Debt-to-Assets	-0.315 ***	-0.287 ***	-0.299 ***
	(-6.22)	(-4.31)	(-3.94)
Historical Volatility	5.124 ***	5.043 ***	3.792 ***
	(4.35)	(4.63)	(3.84)
Historical Return	-0.0344	-0.0850 ***	-0.174 ***
	(-1.16)	(-2.72)	(-4.27)
N	36,710	36,710	36,710
Pseudo R^2	0.0725	0.0938	0.106

Table 5 Notes:
***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

This table shows the results of a probit regression where the dependent variable is equal to 1 for extreme earnings-related returns, and 0 otherwise. Extreme earnings-related returns are observations where the firm experienced a cumulative return of -10%/-15%/-20% or less over the three days surrounding the earnings announcement.

Skew is the difference in implied volatility between Category 2 (out-of-the-money) puts and Category 3 (at-the-money) calls. *ATM IV* is the average implied volatility for all Category 3 options. *Log(Market Value)* is the logarithm of the firm's market value. *Skew ATM IV*, and *Log(Market Value)* are measured three trading days prior to the earnings announcement. *Book-to-Market* is the ratio of the firm's common equity from the prior quarter to the pre-earnings market value. *Debt-to-Assets* is the ratio of total debt to total assets from the prior quarter. *Historical Volatility* is the standard deviation of daily stock returns for the 90 days prior to the earnings announcement, and *Historical Return* is the buy-and-hold stock return for the 90 days prior to the earnings announcement.

All independent variables are winsorized at the 1% and 99% levels. All standard errors are based on clustering at the 2-digit SIC level.

Table 6 - Change in Implied Volatility Function after earnings announcements

	Post-Earnings - Pre-Earnings Change					Pre-Earnings Level	
	N	Mean	Median	25th Percentile	75th Percentile	Mean	Median
At-The-Money IV	43,988	(0.023)	(0.016)	(0.053)	0.010	0.528	0.478
Skew	27,441	(0.001)	(0.001)	(0.023)	0.020	0.042	0.035

Table 6 Notes:
This table summarizes the change in *At-The-Money IV* and *Skew* from three trading days prior to the earnings announcement to three trading days following the earnings announcements (i.e., negative numbers are decreases). *At-The-Money IV* is the average of all Category 3 options with positive open interest. *Skew* is the difference between Category 2 (Out-of-the-money) puts and Category 3 (At-the-money) calls.

Table 7 – Predictability of Extreme Earnings Announcement Returns
Panel A: Cumulative non-earnings returns

Independent Variables	Dependent Variable: Probability of experiencing cumulative non-earnings-related returns of: <=-10%	<=-15%	<=-20%
Skew	0.840***	0.893***	0.755***
	(3.91)	(3.79)	(3.97)
ATM IV	0.868***	1.075***	1.276***
	(10.08)	(13.10)	(11.79)
Log(Market Value)	-0.0224***	-0.0289***	-0.0224***
	(-3.20)	(-3.67)	(-3.14)
Book-to-Market	0.0353	0.0461	0.0682*
	(1.06)	(1.32)	(1.65)
Debt-to-Assets	-0.0236	0.00242	0.0166
	(-0.51)	(0.07)	(0.42)
Historical Volatility	4.298***	4.442***	4.369***
	(3.76)	(4.20)	(3.46)
Historical Return	0.0742	0.0569	0.0314
	(1.43)	(1.25)	(0.64)
N	34,049	34,049	34,049
Pseudo R^2	0.0404	0.0585	0.0754

(See notes following Panel B)

Table 7 – Predictability of Extreme Earnings Announcement Returns
Panel B: Single-day non-earnings returns

Independent Variables	**Dependent Variable: Probability of experiencing single-day non-earnings-related returns of:** **<=-10%**	**<=-15%**	**<=-20%**
Skew	0.522 **	0.612 **	0.671
	(2.54)	(2.35)	(1.59)
ATM IV	2.767 ***	2.167 ***	1.847 ***
	(30.16)	(21.69)	(12.87)
Log(Market Value)	0.00855	-0.00934	-0.0374 ***
	(1.45)	(-1.01)	(-3.55)
Book-to-Market	-0.0559	-0.00262	-0.0264
	(-1.04)	(-0.04)	(-0.38)
Debt-to-Assets	-0.152 ***	-0.0394	0.0235
	(-3.76)	(-0.75)	(0.34)
Historical Volatility	7.585 ***	4.102 ***	2.044
	(7.00)	(3.33)	(1.08)
Historical Return	0.186 ***	0.0366	0.0001
	(4.15)	(0.62)	(0.00)
N	34,049	34,049	34,049
Pseudo R^2	0.239	0.186	0.153

Table 7 Notes:
***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

This table shows the results of a probit regression where the dependent variable is equal to 1 for extreme non-earnings-related returns, and 0 otherwise. Extreme earnings-related returns in Panel A are observations where the firm experienced a cumulative return of -10%/-15%/-20% or less from three days after the current earnings announcement to three days prior to the next earnings announcement. Extreme returns in Panel B are observations where the firm experienced a single-day stock return of -10%/-15%/-20% or less during the same period.

Skew is the difference in implied volatility between Category 2 (out-of-the-money) puts and Category 3 (at-the-money) calls. *ATM IV* is the average implied volatility for all Category 3 options. *Log(Market Value)* is the logarithm of the firm's market value. *Skew*, *ATM IV*, and *Log(Market Value)* are measured three trading days after the earnings announcement. *Book-to-Market* is the ratio of the firm's common equity from the prior quarter to the pre-earnings market value. *Debt-to-Assets* is the ratio of total debt to total assets from the prior quarter. *Historical Volatility* is the standard deviation of daily stock returns for the 90 days prior to the earnings announcement, and *Historical Return* is the buy-and-hold stock return for the 90 days prior to the earnings announcement.

All independent variables are winsorized at the 1% and 99% levels. All standard errors are based on clustering at the 2-digit SIC level.

Table 8 – Predictability of Extreme Returns
Panel A: Management Earnings Forecast Periods

Independent Variables	Dependent Variable: Probability of experiencing 3-day forecast period returns of: <=-10%	<=-15%	<=-20%
Skew	-0.623	-0.643	-0.845
	(-1.50)	(-1.25)	(-1.55)
ATM IV	1.394 ***	1.517 ***	1.470 ***
	(10.01)	(8.05)	(6.99)
Log(Market Value)	-0.115 ***	-0.138 ***	-0.144 ***
	(-7.92)	(-8.31)	(-8.12)
Book-to-Market	-0.233 ***	-0.249 ***	-0.352 ***
	(-3.37)	(-3.10)	(-3.64)
Debt-to-Assets	-0.152	-0.161	-0.164
	(-1.37)	(-1.44)	(-1.29)
Historical Volatility	3.806	2.700	2.999
	(1.47)	(1.02)	(1.08)
Historical Return	-0.158 ***	-0.0323	-0.0337
	(-2.89)	(-0.69)	(-0.71)
N	6,743	6,743	6,743
Pseudo R^2	0.122	0.143	0.150

(See notes following Panel B)

Table 8 – Predictability of Extreme Returns
Panel B: Dividend Declaration Periods

Independent Variables	Dependent Variable: Probability of experiencing 3-day forecast period returns of: <=-10%	<=-15%	<=-20%
Skew	0.950	0.525	2.273 ***
	(1.48)	(0.71)	(2.91)
ATM IV	2.282 ***	2.342 ***	1.844 **
	(6.48)	(3.80)	(2.26)
Log(Market Value)	0.0490	0.0529	0.0465
	(1.58)	(1.10)	(0.70)
Book-to-Market	0.0143	0.0219	0.00543
	(0.14)	(0.16)	(0.03)
Debt-to-Assets	0.110	0.390	0.836 **
	(0.56)	(1.52)	(2.03)
Historical Volatility	0.593	-3.672	-0.903
	(0.16)	(-0.47)	(-0.09)
Historical Return	0.0106	0.138	0.170
	(0.07)	(0.98)	(0.55)
N	9,447	9,447	9,447
Pseudo R^2	0.109	0.113	0.134

Table 8 Notes:
***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

This table shows the results of a probit regression where the dependent variable is equal to 1 for extreme non-earnings-related returns, and 0 otherwise. Extreme earnings-related returns in Panel A are observations where the firm experienced a 3-day return of -10%/-15%/-20% or less around management earnings forecasts. Extreme returns in Panel B are observations where the firm experienced a 3-day return of -10%/-15%/-20% or less around dividend declarations.

Skew is the difference in implied volatility between Category 2 (out-of-the-money) puts and Category 3 (at-the-money) calls. *ATM IV* is the average implied volatility for all Category 3 options. *Log(Market Value)* is the logarithm of the firm's market value. *Skew*, *ATM IV*, and *Log(Market Value)* are measured three trading days after the earnings announcement. *Book-to-Market* is the ratio of the firm's common equity from the prior quarter to the pre-earnings market value. *Debt-to-Assets* is the ratio of total debt to total assets from the prior quarter. *Historical Volatility* is the standard deviation of daily stock returns for the 90 days prior to the earnings announcement, and *Historical Return* is the buy-and-hold stock return for the 90 days prior to the earnings announcement.

All independent variables are winsorized at the 1% and 99% levels. All standard errors are based on clustering at the 2-digit SIC level.

Table 9 – Determinants of Implied Volatility Skew

Independent Variables	(1)	(2)	(3)
Log(Market Value)	0.000	0.001	0.001
	(-0.12)	(0.93)	(0.96)
Book-to-Market	0.018 ***	0.018 ***	0.018 ***
	(4.32)	(4.48)	(4.47)
Debt-to-Assets	0.011 ***	0.011 ***	0.011 ***
	(4.03)	(4.19)	(4.19)
Historical Volatility	0.619 ***	0.312 *	0.346 *
	(7.27)	(1.82)	(1.96)
Historical Return	-0.012 ***	-0.012 ***	-0.012 ***
	(-7.50)	(-7.72)	(-7.56)
At-the-Money IV		0.028 *	0.028 *
		(1.85)	(1.87)
Single Day 10% price drop			-0.002
			(-1.64)
N	34,049	34,049	34,049
R^2	0.035	0.037	0.037

Table 9 Notes:
***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

This table shows the results of an OLS regression where the dependent variable is *Skew*, measured three trading days after the earnings announcement. *Skew* is the difference in implied volatility between Category 2 (out-of-the-money) puts and Category 3 (at-the-money) calls.

Log(Market Value) is the logarithm of the firm's market value. *Book-to-Market* is the ratio of the firm's common equity from the prior quarter to the pre-earnings market value. *Debt-to-Assets* is the ratio of total debt to total assets from the prior quarter. *Historical Volatility* is the standard deviation of daily stock returns for the 90 days prior to the earnings announcement, and *Historical Return* is the buy-and-hold stock return for the 90 days prior to the earnings announcement. *At-the-Money IV* is the average implied volatility for all Category 3 options.

All independent variables are winsorized at the 1% and 99% levels. All standard errors are based on clustering at the 2-digit SIC level.