Earning Surprise and Implied Volatility: Could New Information Increase Uncertainty?

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Abstract

Simple Bayesian learning models, such as those proposed by Lewellen and Shanken (2002) and Pastor and Veronesi (2003, 2006), suggest that new (additional) information reduces posterior variance of investor expectation for the unobservable. Consistent with such common wisdom, Dubinsky and Johannes (2006) and Barth and So (2013) show that implied volatility is high before earnings annoucement and then decreases, after the uncertainty resolves. However, Veronesi (1999) illustrates that suppose realized signal deviating sufficiently from expected values, investors may revise their beliefs significantly and uncertainty towards future will increase. Motivated by Veronesi's model, we ask the research question: could there be a positive relation between earning surprise magnitude and future volatility? In the paper, we treat earning surprise as a measure of deviation between realized and expected signals, and study its long-term effect on equity implied volatility. Our results suggest that, larger earning surprise magnitude, no matter the news itself is good or bad, will lead to increasing implied volatility in following months, after controlling firm characteristics, heterogeneous belief proxy and other variables related to asset liquidity and informed trading. Moreover, we also find the same pattern for implied volatility change one day after earnings annoucement.

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1 Introduction

Common wisdom for Bayesian learning and various filtering methods suggest that any signals having informational content will reduce the posterior distribution variance for estimated unobserved state variable. Consistent with such intuition, several researchers find that implied volatility will first increase before earning annoucement day and then decrease after information is revealed. Dubinsky and Johannes (2006) report that earnings announcements enhance the uncertainty of a company, defined as the implied volatility. Volatility increases before earnings are announced and decreases after the announcement. Barth and So (2013) find that impllied volatility and volatility spread are larger before the earning annoucements date. The authors argue that such increase could be attributed to investors hedging demand concerned with the uncertainty of earning information. After the earnings annoucement, such uncertainty is resolved, then the influence of earning surprise disappears.

In this paper, we examines the relation between earning surprise and implied volatility from a different perspective. Instead of studying the implied volatility pattern around earning annoucement day, we focus on its long-term effect on implied volatility in following months. Such design is motivated by recent advances in learning literature. Several researchers suggest that if the unobservable fundamental follows a stochastic process with regime shifts, then uncertainty towards the variable could fluctuate stochastically, and return volatility can rise, due to investors may revise their expectations significantly after news comes. In his seminal paper, David (1997) develops a model with unobservable regime shifts in the average productivities of linear technologies, which are subject to learning by a representative agent. Learning induces time-varying allocations to these technologies, resulting in persistent stochastic variation in return volatility. Veronesi (1999) uses similar modeling approach, within Lucas (1978) exchange economy, to show that even if dividends display low constant volatility, stock returns may possess high volatility with persistent variation. He argues that learning about a regime-shifting dividend growth rate generates stock price 'over-reaction' to bad news in good times, because large news surprise makes investors to be increasingly uncertain about the current regime. Such uncertainty increase return volatility. Within such theoretical framework,

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David and Veronesi (2002) employ unobservable regime shifts to explain the dynamics of option-implied volatility and skewness spreads. Veronesi (2004) shows that a small probability of a long recession can induce volatility to cluster at high levels during recessions. David and Veronesi (2013) develop a structural model for volatility forecasting that exploits learning-induced relations between volatility and price multiples. David and Veronesi (2014) link index option implied volatility smile to monetary policy.

Based on analysis in the papers mentioned above, we postulate that, although the earnings annoucement conveys certain information, it is possible that if the realized value is significantly different from their expectation, investors could become more uncertain about firm fundamentals and need to revise their beliefs. Such behavior leads to increasing expected volatility and generate long-term effect after earning annoucement. To test such hypothesis, we use earning surprise to proxy the difference between realized and expected beliefs. In our paper, earning surprise is defined as the *absolute value of difference between firm's true earning and mean of analysts' forecast, scaled by stock price*[1]. The motivation for scaling earning surprise by stock price is discussed in details in later section. Using a sample of US firms with financial, market, analyst, and options data spanning 1996-2012, larger earning surprise magnitude, no matter the news itself is good or bad, will lead to increasing implied volatility in following months, after controlling firm characteristics, heterogeneous belief proxy and other variables related to asset liquidity and informed trading.Larger earning surprise magnitude also generates higher firm default probability and bond returns. Moreover, we also find the same pattern for implied volatility change one day after earnings annoucement. In other words, our results show that the magnitude of news matters, which is consistent with our hypothesis.

The contribution of the paper lies in the fact that we identify a new and long-term relation between earning surprise and implied volatility. All researchers focus on relation about earning surprise and volatility around earning annoucement, and most of them document a first-increase-then-decrease pattern for implied volatility and volatility spread. The authors argue that such pattern is due to

[1] We also scale the raw earning surprise by firm last quarter book value and past three-year earning volatility, results still hold.

investors hedging demand concerned with the uncertainty of earning information. After the earnings annoucement, such uncertainty is resolved, then the influence of earning surprise disappears. One exception is Xing and Zhang (2013) study. In their paper, the authors show that straddles earn positive returns the day after earning annoucement, which means that realized volatility on that day could be larger than expected. Therefore, the authors link investor's conservatism to the positive returns.

Our paper is significantly different from theirs. On the one hand, we show a new empirical result, long-term effect of *magnitude* of earnings surprise on implied volatility. On the other hand, our empirical design gives us a clean test for different implication from investor learning models, which cannot be achieved by examining volatility pattern right after the earning annoucement. Since right after the earning annoucement day, according to the sign of earning surprise, the price will change. As long as price moves, volatility will increase. Therefore, *magnitude* of earnings surprise could affect volatility mechanically. However, if we consider long-run effect, simple Bayesian learning models suggest that larger realized earnings than expectation should be good news, therefore, in the long run, volatility should decrease, because investors will regard such firm less risky. Similarly, worse realized earnings than expectation will increase volatility. In contrast, if investors tend to revise their beliefs given large magnitude of earning surprise, both good news and bad news could increase volatility. Such difference allows us to distinguish among different learning patterns.

The structure for the rest of this paper is as follows. Section 2 reviews the related literature. Section 3 motivates our choice of empirical proxy for earning surprise (information innovation). Section 4 outlines the empirical framework. Section 5 presents and discusses results. Section 6 makes conclusions and provides some possible directions for future research.

2 Literature Review

This paper is closed related to three streams of literature. The first research area is investors' learning behavior and its effects on equity return and volatility. Several researchers link investors' learning behavior and equity premium. Timmermann (1993) provides a simple learning model, in which average dividend growth is unknown. Investors have to get their own estimation from observed dividend process. In such case, the author shows that dividend surprise affects stock price not only through current dividends but also through the effect on expected dividend growth rate, which also changes expected future dividends. Pastor and Veronesi (2003) provide a model with market-to-book ratio as the only state variable. It is observable, yet its long term mean is unknown to investors. Pastor and Veronesi (2006) calibrate the model to value stocks at the time of Nasdaq bubble. They find a positive link between uncertainty about average dividend growth and the level of stock prices. Pastor and Veronesi (2009) study the similar idea in a more detailed model. In the model, future productivity of new technology should be learned by investors. The authors model the process of technology adaption, and use it to explain the different pattern of stock returns for new and old technology firms.

Besides equity risk premium, all these papers mentioned above also point out that investors learning behaviors could be an important channel to generate the excess volatility (Grossman and Shiller, 1981). Since the signals about unobservable state variables contain uncertainty (noise), the learning process introduces another source of volatility different from fundamental uncertainty. Therefore, the stock volatility should be larger than the fundamental ones. This intuitive idea is explored by other researchers in different settings. Brennan and Xia (2001) find that non-observability of the expected dividend growth rate introduces an element of learning which increases the volatility of stock price. Bansal and Shaliastovich (2011) show that since information acquiring process is costly, the optimal decision to incur a cost and learn the true economic state can generate sudden change in stock prices, that is, jumps. Benzoni, Collin-Dufresne and Goldstein (2011) build a general equilibrium framework in which expected endowment growth and economic uncertainty are subject to rare jumps. The arrival of a jump triggers investors' learning about the likelihood of future jumps, which produces a permanent shift in option prices and implied volatility smiles. David (2008) shows that investors' learning about the state of future real economic fundamentals from current inflation leads to macroeconomic state dependence of asset valuations and solvency ratios of firms within given rating categories. Such state dependence feature and increasing price of risk generate high credit spreads while maintaining average default losses at historical levels.

This paper is also related to various studies on cross section implied volatility. The focus of option pricing literature is mainly on index option. The implied volatility term structure and pricing factors for individual equity options earn much less attention. Pioneer researchers in this area start to examine the effect of systematic risk on individual option implied volatility. Duan and Wei (2009) argue that systematic risk proportion can help differentiate the price structure across individual equity options. After controlling the underlying asset total risk, a higher amount of systematic risk leads to a higher level of implied volatility and a steeper slope of the implied volatility curve. Elkamhi and Ornthanalai (2010) examine the role of market jump risk premium implicit in individual equity options and find out that market jump risk embedded in equity options is about 3.18%. Driessen, Maenhout and Vilkov (2009) find that market-wide correlation risk exposure can explain the cross-section of index and individual option returns. Christoffersen, Fournier and Jacobs (2013) conduct a principal component analysis for implied volatility surface of equity options on Dow-Jones firms and reveal a strong factor structure. The first principal component explains 77% of the variation in the equity volatility level, 49% of the variation in the equity option skew and 57% of the implied volatility term structure across equities. Furthermore, the first principal component has a 91% correlation with S&P500 index option volatility, a 42% correlation with the index option skew, and a 74% correlation with the index option term structure.

Apart from traditional risk based models, demand-based option pricing theory also provides explanation for individual implied volatility curve. Bollen and Whaley (2004) demonstrate that changes in implied volatility are correlated with signed option volume. Gârleanu, Pedersen, and Poteshman (2009) argue that option expensiveness is related to exogenous demand pressure in imperfect markets. The authors develop a theoretical model of option intermediation in which risk-averse market makers provide immediacy and are compensated for inventory risk. Investors are assumed to supply/demand options for exogenous reasons: portfolio insurance, covered call writing, agency issues, or behavioral reasons. Market makers trade a portfolio of options on a given security and are allowed to hedge in the underlying at discrete time intervals. Thus, part of the option's risk can be hedged away. The key insight in their paper is that demand pressure for a given option increases its price by an amount proportional to the variance which it contributes to the market makers optimally hedged/diversified portfolio. Their analysis focuses on a cross-section of options on a given underlying security, and can be extended for options on a cross-section of underlying stocks.

Additionally, some researchers link firm's activities with its implied volatility of traded options. Lyle (2012) shows evidence that accounting quality is significantly associated with the expected returns of call and put options. Goodman, Neamtiu and Zhang (2013) investigate whether fundamental accounting information is appropriately priced in the options market. The authors find that fundamental accounting signals, such as earnings, accruals and Dupont measure, exhibit incremental predictive power with respect to future option returns above and beyond what is captured by implied and historical stock volatility, suggesting that the options market does not fully incorporate fundamental information into option prices.

Moreover, the effect of transaction cost is also considered. Chou et al. (2011) illustrate the impact of both spot and option liquidity on option prices. Using implied volatility to measure the option price structure, their empirical results reveal that even after controlling the systematic risk of Duan and Wei (2009), a clear link remains to exist between option prices and liquidity. Christoffersen et al. (2012) report the existence of illiquidity premia in equity option markets using a large cross-section of firms. An increase in option illiquidity decreases the current option price and predicts higher expected delta-hedged option returns.

This paper is also built on researches about variance premium. Empirically, Bakshi and Kapadia (2003a, b) show the existence of a negative market volatility risk premium in index and individual stock options has effect on delta-hedged option returns. Bali and Hovakimian (2009) show that volatility spreads have prediction power over cross-section stock returns. Goyal and Saretto (2009) study the cross-section of stock option returns by sorting stocks on the difference between historical realized volatility and at-the-money implied volatility. They find that a zero-cost trading strategy that is long (short) in the portfolio with a large positive (negative) difference between these two volatility measures produces an economically and statistically significant average monthly return.

Theoretically, Bakshi and Madan (2006) identify the sufficient conditions on physical and risk-neutral densities that give rise to positive volatility spreads. Bollerslev, Tauche and Zhou (2009) and Drechsler and Yaron (2011) illustrate the source of variance premium via general equilibrium asset pricing models. Both papers postulate that the return predictability power arises because the time-series of the variance risk premium and the equity risk premium are correlated. Bollerslev, Tauchen and Zhou (2009) derives this correlation in a discrete-time model with time variation in both consumption volatility and the volatility of consumption volatility. They show that the variance risk premium captures time variation in the volatility of consumption volatility, which is also correlated with the time variation in risk premium. Drechsler and Yaron (2011) derives the correlation between equity and variance risk premium in a broader setting that incorporates the long-run risk dynamics in Bansal and Yaron (2004) and jumps in consumption growth and its volatility. In their model, the variance risk premium comes from priced jump risk.

While theories for variance premium mentioned above are all within the representive agent framework, Buraschi and Jiltsov (2006) first provides option pricing and volume implications for an economy with heterogeneous agents who face model uncertainty and have different beliefs on expected returns. Market incompleteness makes options nonredundant, while heterogeneity creates a link between differences in beliefs and option volumes. The authors find that once information heterogeneity is considered, the model can explain the dynamics of option volume and the smile better than can reduced-form stochastic volatility model. Based on this model, Buraschi, Trojani and Vedolin (2014) produce evidence for an equilibrium link between investors' disagreement, the market price of volatility and correlation, and the differential pricing of index and individual equity options. The authors show that belief disagreement is positively related to (i) the wedge between index and individual volatility risk premia, (ii) the different slope of the smile of index and individual options and (iii) the correlation risk premium.

Besides researches focusing on index option, several studies shed lights on individual variance premium. Han and Zhou (2011) find that cross section variance premium is significantly related to stocks' sensitivities to common risk factors. In particular, stocks whose returns tend to be low when systematic volatility increases have higher variance risk premium. Barth and So (2013) identify factors associated with equity volatility and risk premia around quarterly earnings announcements. The authors find the firm's information environment related to earnings, earnings uncertainty, and prior quarterly earnings announcement market reactions can explain realized volatility, volatility implied by prices of the firm's traded call options, and risk premia measured as implied volatility minus realized volatility. Their results demonstrate that, on average, implied volatility around earnings announcements exceeds realized volatility, which is evidence of option prices reflecting a jump risk premium. Buraschi, Trojani and Vedolin (2014) build an equilibrium link between investors disagreement, the market price of volatility and correlation, and the differential pricing of index and individual equity options.

Roughly speaking, variance premium is equivalent to delta-hedged call/put option returns or at-the-money straddle returns. Therefore, this paper is also related to the literature about cross section option returns. Coval and Shumway (2001) examine the returns on delta-hedged option positions, at-the-money straddle, and find average returns close to minus 3% per week. They suggest is evidence that some other systematic factor, such as stochastic volatility, might be priced by the market. Similar conclusions are made by Jackwerth (2000), who finds risk-adjusted profitability from selling puts, and by Bakshi and Kapadia (2003), who find that the volatility risk premium contributes significantly to higher prices for calls and puts. Buraschi and Jackwerth (2001) concur, suggesting that more than one priced risk factor is necessary to explain option prices. Vasquez (2012) find that the slope of the implied volatility term structure is positively related with future option returns. Goyal and Saretto (2009) study the cross-section of stock option returns by sorting stocks on the difference between historical realized volatility and at-the-money implied volatility. They find that a zero-cost trading strategy that is long (short) in the portfolio with a large positive (negative) difference between these two volatility measures produces an economically and statistically significant average monthly return. Cao and Han (2012) present a robust new finding that delta-hedged equity option return decreases monotonically with an increase in the idiosyncratic volatility of the underlying stock. This result cannot be explained by standard risk factors and is distinct from existing anomalies in the stock market or volatility-related option mispricing. It is consistent with market imperfections and constrained financial intermediaries. Dealers charge a higher premium for options on high idiosyncratic volatility stocks due to their higher arbitrage costs. Controlling limits to arbitrage proxies reduces the strength of the negative relation between delta-hedged option return and idiosyncratic volatility by about 40%. Boyer and Vorkink (2013) investigate the relationship between ex-ante total skewness and holding returns on individual equity options. They find, consistent with skewness preference theory proposed by Barberis and Huang (2008), that total skewness exhibits a strong and negative relationship with average option returns.

3 Motivation of Proxy for Earning Surprise

The information innovation is the difference between investors' belief and realized value. In the paper, we define our proxy as follows

$$SUE = \frac{realized\ earning - mean(analyst\ forecast)}{stock\ price}.$$

where SUE is earning surprise widely used in literature. We represent investors' belief by the mean of analysts' forecasts. SUE is calculated as the gap between investors' belief and realized real firm earnings. The scalor is stock price on earning annoucement day. We incorporate investors' learning behavior in the stock valuation model proposed by Bakshi and Chen (2005) to motivate our choice of empirical measure for information innovation.

Following Bakshi and Chen (2005), we consider a continuous-time, infinite-horizon economy with an exogenously specified pricing kernel, M_t. For a firm in this economy, the stock price, P_t is given by standard discounted-cash-flow formula

$$P_t = \int_t^{\infty} \mathbf{E}_t[\frac{M_\tau}{M_t} D_\tau] d\tau,$$

where $\mathbf{E}_t(\cdot)$ is the conditional expectation under physical measure. $D_(\tau)$ is dividend per share paid out over a period $d\tau$. Let us use Y_t to represent earnings per share, then

$$D_t dt = \delta Y_t dt + dW_{d,t},$$

where δ is the constant payout ratio, same settings as those in Bakshi and Chen (2005).

The EPS dynamics Y_t follows a diffusion process

$$\frac{dY_t}{Y_t} = \mu_t dt + \sigma_y dW_{y,t},$$

with stochastic growth rate following O-U process

$$d\mu_t = \kappa(\theta - \mu_t)dt + \sigma_\mu dW_{\mu,t}.$$

The exogenous pricing-kernel is define as

$$\frac{dM_t}{M_t} = -rdt - \sigma_m dW_{m,t},$$

where r is the constant risk-free rate. The correlation between $(dW_{y,t},\ dW_{\mu,t})$, $(dW_{m,t},\ dW_{y,t})$, $(dW_{m,t},\ dW_{\mu,t})$ are ρ, ρ_{my} and $\rho_{m\mu}$.

We introduce learning to the model by assuming that investors cannot observe and need to learn EPS mean growth rate μ_t from past EPS observations. Using standard one-dimensional linear filtering theory based on Lipster and Shiryaev (2001),the solution for filtered estimation $\hat{\mu}_t$ is given by

$$\begin{aligned} d\hat{\mu}_t &= \kappa(\theta - \hat{\mu}_t)dt + \hat{\sigma}_\mu dW^*_{y,t}, \\ \frac{d\omega_t}{dt} &= -\frac{1}{\sigma_y^2}\omega_t^2 - 2(\rho\frac{\sigma_\mu}{\sigma_y} + \kappa)\omega_t + \sigma_\mu^2(1-\rho^2). \end{aligned}$$

where $\omega_t = \mathbf{E}_t[(\mu_t - \hat{\mu}_t)^2]$ is the posterior variance for $\hat{\mu}_t$, satisfying an ODE. The diffusion term of $\hat{\mu}_t$ dynamics is given by

$$\hat{\sigma}_\mu = \frac{\omega_t}{\sigma_y^2} + \rho\frac{\sigma_\mu}{\sigma_y},$$

and

$$dW^*_{y,t} = \frac{1}{\sigma_y}(\frac{dY_t}{Y_t} - \hat{\mu}_t dt),$$

is Brownian motion under investor's belief. In steady-state, we let $d\omega_t/dt = 0$, then posterior variance ω_t becomes

$$\overline{\omega} = \frac{1}{2}(-(\rho\sigma_\mu\sigma_y + \kappa\sigma_y^2) + \sqrt{(\rho\sigma_\mu\sigma_y + \kappa\sigma_y^2)^2 + \sigma_\mu^2\sigma_y^2(1-\rho^2)}).$$

Then diffusion term for $\hat{\mu}_t$ is given by $\hat{\sigma}_\mu = \overline{\omega}/\sigma_y^2 + \rho\sigma_\mu/\sigma_y$.

In summary, under learning framework and investor's belief, the system becomes

$$\frac{dY_t}{Y_t} = \hat{\mu}_t + \sigma_y dW^*_{y,t},$$
$$d\hat{\mu}_t = \kappa(\theta - \hat{\mu})dt + \hat{\sigma}_\mu dW^*_{y,t}.$$

Based on analysis of Bakshi and Chen (2005), we know that equilibrium stock price is given by

$$P_t = \delta Y_t \int_0^\infty z(\tau, \hat{\mu}_t)d\tau = \delta Y_t \int_0^\infty \exp(a_\tau + b_\tau \hat{\mu}_t)d\tau,$$

where

$$a_\tau = -\lambda_y \tau - r\tau + \frac{1}{2}\frac{\hat{\sigma}_\mu^2}{\kappa^2}(\tau + \frac{1 - e^{-2\kappa\tau}}{2\kappa} - \frac{2}{\kappa}(1 - e^{-\kappa\tau})) + \frac{\kappa\theta + \sigma_y \hat{\sigma}_\mu}{\kappa}(\tau - \frac{1 - e^{-\kappa\tau}}{\kappa}),$$
$$b_\tau = \frac{1 - e^{-\kappa\tau}}{\kappa}, \quad \lambda_y = \sigma_y \sigma_m \rho_{my}.$$

The analysis above augments Bakshi and Chen (2005) framework with investors' learning. The price/earning ratio contains information about mean growth rate of firm earnings, which is unobservable. According to the formula, the difference between investors' estimated Y/P ratio and realized Y/P ratio is totally driven by difference between estimated growth rate $\hat{\mu}_t$ and realized μ_t.

Therefore, roughly speaking, our definition for SUE in Equation 3 could be treated as

$$\frac{\hat{Y}}{\hat{P}} - \frac{Y}{P} \approx \frac{\hat{Y} - Y}{P} = SUE = f(\hat{\mu}) - f(\mu).$$

Although the relation is not linear and not perfect, the difference of Y/P ratio could be treated as a measure for the gap of $\hat{\mu}$ and μ.

Based on above analysis, larger magnitude of earning surprise indicates wider gap between estimated and true state variable. Therefore, our new and straightforward hypothesis in the paper, based on the learning literature, is given as follows

Hypothesis 3.1. *Larger $|SUE|$ leads to increasing implied volatility,*

which indicates that if information surprise is large, investors may become more uncertain about future, therefore, volatility will increase.

4 Empirical Study Design

In this section, we first give definitions of variables used in our empirical study. After that, the empirical methodology is introduced.

4.1 Data Construction

The option data is obtained from OpenMetrics, which provides daily closing bid and ask quotes, open interest, and trading volume for all listed equity options from Jan 1996 to December 2012. Optionmetrics computes option implied volatilities and greeks based on CRR binomial tree model and constructs the fitted implied volatility surface (separately for calls and puts), which consists of interpolated implied volatilities of standard options with constant maturity and delta. For the empirical analysis, the fitted implied volatilities of options with constant maturities and deltas are used. To calculate daily risk neutral volatility for individual stocks, we average implied volatilities with constant time-to-maturity of 30 days and 0.5 delta. For each month t, the average daily implied volatility is used as an measure for IV_t.

The daily stock data is obtained from CRSP daily stock file. Each day, stock return is calculated as the log difference between today's close price and previous one. Daily realize variance is calculated as the square of open-to-close return. Then the daily realized variance within a month t is aggregated and scaled to get realized variance for month t, RV_t. Following Duan and Wei (2009), the market beta (Beta) for individual stock is calculated via one-year rolling window (250 days), and CRSP's value weighted market return (VWRETD) is used as the market index.

Monthly stock trading volume ($SVOL_t$) is the sum of daily trading volume in month t. The total trading volume of call option in month t is the sum of daily trading volume of call options cross all maturities and moneynesses in that month. The total trading volume of put option in month t is the sum of daily trading volume of put option cross all maturities and moneynesses in month t. The put/call ratio (P/C_t) is the trading volume of put option divided by trading volume of call option in month t. The total option trading volume ($OPVOL_t$) is the sum of total trading volume for all call and put options in month t. The O/S_t ratio in month t is the total option trading volume divided by total trading volume of stock i. The trading volume is scaled by 100 to make it more comparable to the quantity of option contracts that each pertain to 100 shares.

The daily liquidity measure of stocks is the difference between closing ask and bid price scaled by the middle point of these two. The monthly liquidity measure ($SBAS_t$) is the average of daily ones in month t. For daily liquidity measure of options, we first calculate the liquidity for each contract as the difference between closing ask and bid price scaled by the middle point of these two, then taking average as the daily liquidity measure. Monthly liquidity measure for options ($DBAS_t$) is the average of daily ones in month t.

Data on firm characteristics at the end of the fiscal year are obtained from compustat, firm size (SIZE) is the logarithm of firm's total assets. Market leverage ratio (LEV) is total debt of firm scaled by the sum of total debt and firm's equity value. Market to book ratio (MTB) is market value scaled by total asset. Earning volatility is calculated as standard deviation for past three years' Earnings Per Share (Excluding Extraordinary Items).

The calculation of earnings announcement surprise follows the methodology outlined in Livnat and Mendenhall (2006), using a measure of analyst's expectations and reported actual earnings from IBES, scaled by stock price. The measure for analysts' expectations is the median of latest individual analysts forecasts issued within the 90 days prior to the earnings annoucement date. In constructing IBES-Based earnings surprises (SUE_t), unadjusted detail history that does not have adjustments for stock splits and stock dividends is used. This is done to avoid the potential rounding issues in IBES Adjusted data described in Payne and Thomas (2003). Stock split is adjusted using CRSP adjustment factor to put both the forecast and the actual in the IBES Unadjusted data on the same per share basis and to accurately calculate analyst-based SUE. We also calculate the number of analysts making the prediction. As a proxy for heterogeneous beliefs, analyst forecast dispersion $DISP_t$ within these 90 days is calculated as the standard deviation of forecasts, scaled by absolute value of mean forecast. Summary statistics are presented in Table 1.

4.2 Regression Framework

To test the hypothesis, monthly Fama-Mecbeth regression is applied. We show that earnings surprise has a positive effect for future implied volatility, no matter the value is positive or negative. The regression framework is given by

$$
\begin{aligned}
IV_{i,t+1} &= \alpha + \rho IV_{i,t} + \beta|SUE_{i,t}| + \gamma X_{i,t} + \epsilon_{i,t+1}, \\
RV_{i,t+1} &= \alpha + \rho RV_{i,t} + \beta|SUE_{i,t}| + \gamma X_{i,t} + \epsilon_{i,t+1},
\end{aligned} \tag{1}
$$

where $IV_{i,t+1}$ is implied variance. $RV_{i,t+1}$ is realized variance. Since volatility is persistent, we first control the lagged values for $IV_{i,t}$, $RV_{i,t}$. The coefficient β is what we are interested in. To be consistent with our hypothesis, β should be positive and statistically significant. We use only latest available SUE up to month t.

Since empirical studies show that systematic risk factors, liquidity factors and firm characteristics could have influence on option prices, some control variables $X_{i,t}$ should be included in the regression. Generally speaking, five categories of control variables are included in the regression. The first group contains some firm characteristics, such as leverage ratio, firm size and market to book ratio. The second group contains trading frictions. Monthly average bid-ask spread of options is included as a measure of option liquidity. Given that options are contingent assets, arbitrage pricing theory asserts that the liquidity of the underlying asset is also of relevance to the pricing of options. Thus, monthly average bid-ask spread of stocks, as a measure of liquidity for underlying, is also included. The third group of control variable considers the effect of asymmetric information. The ratio of option to stock trading volume (O/S) is used. The ratio of total monthly put to call trading volume is included, as a measure for impact of imbalance in option demand. Moreover, analyst forecast dispersion is added to control difference of opinion. At last, stock momentum is also controlled.

5 Discussion of Results

5.1 Basic Regression Results

Table 2 provides our main empirical results. Consistent with our hypothesis, absolute value of SUE positively predict future realized and implied volatility. The coefficients are statistically and economically significant. One standard deviation increase will increase realized *volatility* by 9.1057% and implied *volatility* by 5.3807%. The impact is at the same level with other widely studied firm characteristics, such as earnings forecast dispersion and past month stock return.

Apart from earnings surprise, in the Fama-Mecbeth regression, we find some other firm characteristics robustly affecting variance and variance spread. The first is liquidity of underlying equity market. The important paradigms of price formation in securities markets developed by Kyle (1985) and Admati and Pfleiderer (1988) suggest that trading by investors with private information imposes significant liquidity costs on market due to adverse selection cost of transaction. Bid-ask spread, as a measure of level of asymmetric information and stock liquidity, will increase. The importance of underlying liquidity in option valuation has long been acknowledged. Simulations conducted by Figlewski (1989) have illustrated the difficulty of implementing dynamic arbitrage strategies. In a frictionless and complete market model, the price of the option can be replicated by trading in the underlying asset and a risk free bond. If the underlying asset is illiquid, this should affect the return on options. Leland (1985) and Boyle and Vorst (1992) provide a theoretical analysis of this effect using a hedging argument. Since hedging is expensive, the price of option should be also expensive to compensate option writers. Consistent with such arguments, larger bid-ask spread of stocks predicts larger variance and more expensive options. One standard deviation increase will increase realized *volatility* by 24.3891% and implied *volatility* by 17.0342%.

Informed trading in option markets should also be important for option prices and implied volatility. The view that informed investors might choose to trade derivatives because of the higher leverage offered by such instruments has long been entertained by academics. A formal treatment of this issue is provided by Easley, O'Hara, and Srinivas (1998), who allow the participation of informed traders in the option market to be decided endogenously in an equilibrium framework. In their model, informed investors choose to trade in both the option and the stock market. In a pooling equilibrium when the leverage implicit in options is large, when the liquidity in the stock market is low, or when the overall fraction of informed traders is high. Empirically, Figlewski and Webb (1993) provide empirical evidence that trading in options contributes to both transactional and informational efficiency of the stock market by reducing the effect of short-sale constraints on stock market, and such trading has significant effects on option prices. Johnson and So (2012) provide theoretical and empirical evidence that informed traders's private information is reflected in O/S, by examining the relation between O/S and future returns. The authors find that contrasting publicly available totals of firm-specific option and equity volume portends directional prices changes; in particular that low O/S firms outperform the market while high O/S firms underperform. They argue that the negative relation between O/S and future returns is driven by short-sale costs in equity markets, which makes option markets an attractive venue for traders with negative news. Our results in Table 2 extend Johnson and So (2012) results to show that option to stock return volume ratio also affects the expensiveness of individual stock options. One standard deviation increase will increase realized *volatility* by 9.5069% and implied *volatility* by 5.9855%.

Besides, analyst forecast disperion is applied as a control variable for heterogeneous effect. Miller (1977) argues that in the presence of short-sales constraints, divergence of opinions leads to overvaluation and lower future returns. Following such intution, analyst forecast dispersion is shown to have influence on cross section stock return by Diether, Malloy and Scherbina (2002). As for volatility, Dumas, Kurshev and Uppal (2009) show that difference-of-opinion can generate excess volatility for stock returns. Buraschi and Jiltsov (2006) and Li (2013) show that heterogenoues beliefs can affect implied volatility. Buraschi, Trojani and Vedolin (2014) provide cross sectional empirical evidence about analyst forecast dispersion and variance premium. Consistent with such arguments, the coefficient for analyst forecast dispersion is positive and significant in Table 2. One standard deviation increase will increase realized *volatility* by 10.9685% and implied *volatility* by 6. 4111%.

In addition, demand of options could affect price of options, equivalently, implied volatilities, according to Garleanu, Pedersen, and Poteshman (2009). Pan and Poteshman (2006) construct put-call ratios from option volume initiated by buyers to open new positions, and find that option trading volume contains information about future stock prices. Ni, Pan, and Poteshman (2008) show the link between option demand and stock volatility. The authors construct non-market maker net demand for volatility from the trading volume of individual equity options and find that this demand is informative about the future realized volatility of underlying stocks. Another finding of paper is that the impact of this demand on option prices is positive. Due to the data limitation, in our paper, put/call trading volume ratio (P/C) is constructed by total put and call trading volumes. Inconsistent with intuition, large put/call volume ratio predict less variance and variance premium. One standard deviation increase will decrease realized *volatility* by 6.0090% and implied *volatility* by 3.7835%. Such phenomena deserves future investigation.

The coefficient for firm size is significantly negative. One standard deviation increase will decrease realized *volatility* by 19.4707% and implied *volatility* by 11.2893%. One probability is that size is positively associated with the number of individuals who are interested in a firm and therefore know about it, which is consistent with Merton (1987) model. Because financial analysts and the financial press tend to follow large firms, investors may have less information about smaller firms. According to the theory, investors will demand more risk premium for stocks of small firms, that is, is larger, which leads to larger variance premium. A second possibility is that firm size proxies for trading volume and the latter is related to investor attention. The intuition is provided by the literature which studies the high volume return premium. Gervais, Kaniel and Mingelgrin (2001, JF) document that stocks experiencing unusually high (low) trading volume over a day or a week tend to appreciate (depreciate) over the course of the following month. Kaniel, Ozoguz and Starks (2012, JFE) provide international evidence about the high volume return premium puzzle. The common explanation is based on Merton (1987) information model; higher trading volume means the stock draws more attention of investors.

The coefficient for leverage ratio is significantly positive. One standard deviation increase will decrease realized *volatility* by 19.4707% and implied *volatility* by 11.2893%. A growing body of empirical work indicates that common factors may affect the equity risk premium and credit risk on corporate bonds. In particular, there is now substantial evidence that credit risk can be predicted by movements in stock-return volatility (realized or implied volatility). Cao, Yu and Zhong (2010) shows that implied volatility has an explanatory power for credit spread beyond historical volatility. Cremers, Driessen and Maenhout (2008) extract jump premium from option prices and show that it has a strong explanatory power for spreads. Zhang, Zhou, and Zhu (2009) shows that, in addition to historical volatility, jump risk have large explanatory power of default risk. Further, Wang, Zhou and Zhou (2013) show that, apart from volatility, the variance risk premium is a key determinant of firm-level credit spreads. In the opposite direction, credit risk and capital structure could also affect option prices. The intuition is based on Merton (1974) structure model, which views stock as a call option written on leveraged firm assets. Then stock option is a compound option. Following such thoughts, Geske (1979) builds a compound option pricing model to show that firm capital structure should affect option price. Carr and Wu (2010) develop a dynamically consistent framework that allows joint valuation and estimation of stock options and credit default swaps written on the same reference company. Buraschi, Trojani and Vedolin (2010) model the joint behavior of credit spread and stock options when investors disagree. The result for leverage ratio in Table 2 is consistent with these models.

5.2 Further Evidence

Besides investors' learning mechnism, an alternative explanation could be that if the earning surprise is positive, which means there is unexpected good news, investors may think that future prospective of firm is good, stock price could increase, then they will buy more call options, pushing up the implied volatility for calls. Then, generate positive β. Following the same logics, suppose that the earnins surprise is negative, investors may want to buy put options, pushing up the implied volatility for puts. Then, again, generate positive β. We argue from three aspects, such extrapalative expectation could less likely to be the channel through which earning surprise affects implied volatility.

First of all, we divide the whole sample into two subsamples, according to the sign of earning surprise. Then we use follow Fama-Mecbeth regression in each subsample

$$\begin{aligned}
IVC_{i,t+1} &= \alpha + \rho IVC_{i,t} + \beta SUE_{i,t} + \gamma X_{i,t} + \epsilon_{i,t+1}, \\
IVP_{i,t+1} &= \alpha + \rho IVP_{i,t} + \beta SUE_{i,t} + \gamma X_{i,t} + \epsilon_{i,t+1}, \\
IVPC_{i,t+1} &= \alpha + \rho IVPC_{i,t} + \beta SUE_{i,t} + \gamma X_{i,t} + \epsilon_{i,t+1},
\end{aligned} \tag{2}$$

where $IVPC_t = IVP_t - IVC_t$, averaged among the trading days in month t. For the alternative theory to hold, positive SUE should increase implied volatility of call more than put. β in the first two regression should be positive and significant. β in the third regression should be negative and significant. Meanwhile, negative SUE should increase implied volatility of put more than call. β in the first two regressions should be negative and significant. β in the third regression should also be negative and significant. However, Table 3 and 4 both show that the effect of earnings surprise on implied call and put options are almost at the same level. Both positive and negative earnings surprise will increase implied volatility, while β in the 3th regression is always insignificant.

Secondly, we examine the good news and bad news hypothesis using another asset, corporate bonds. On one hand, we calculate Merton's distance to default, according to the method described in Bharath and Shumway (2008). If positive earnings surprise represents good news only, it is unlikely that the default probability could increase. However, Table 5 show that in the case that earnings surprise is positive, the default probability still increases. Such empirical results is consistent with our hypothesis: larger gap indicates a more uncertain future. Large volatility will increase the probability that the firm asset hits the default boundary, herence, increases the default probability. On the other hand, Table 6 confirm our hypothesis in the context of corporate bond yield. Positive earning surprise will also increase the average yield of traded corporate bond. Such effect is less likely triggered by good cash flow news.

Moreover, we further conduct cross section regressions (1) within subsamples, divided by variables related to firm's information environment. To be consistent with our hypothesis, β should be smaller or even insignificant for firms with better information environment. Since for firms with more transparent information system, the noise of signals will be lower, and investors will learn the latent variable with higher accurary. High idiosyncratic volatilty indicates that firms could have more uncertainties about its economic activities and fundamentals. Therefore, the learnings accuracy could be low. Table 7 shows thatin subsamples with high idiosyncratic volatilitythe effect for earnings surprise is stronger. The coefficient is roughly three times larger then the one in subsample with low idiosyncratic volatility. Firm size is another important factor for investor learning. Large firms have more analyst and media coverage, and draw more attention from investors. In Table 8, the effect of earnings surprise is around 1.7 times larger in small firms, compared with the one in large firms. Moreover, Pastor and Veronesi (2003) use firm age as a proxy for learning errors. Table 9 shows that the effect for earning surprise is two times stronger in young firms than the one in mature firms.

Therefore, based on the arguments above, the good-and-bad-signal hypothesis is less likely to be the reason behind our results in Table 2.

5.3 Short-Term Patterns

We further examine the relation between percentage change of implied volatility and earning surprise, one day after earnings annoucement . The regression framework is as follows

$$\frac{IV_{i,+1} - IV_{i,0}}{IV_{i,0}} = \alpha + \rho_1 IV_{i,0} + \rho_2 CashVol_{i,0} + \beta|\overline{SUE}_{i,0}| + \gamma X_{i,0} + \epsilon_{i,+1},$$
$$\frac{RV_{i,+1} - RV_{i,0}}{RV_{i,0}} = \alpha + \rho_1 RV_{i,0} + \rho_2 CashVol_{i,0} + \beta|\overline{SUE}_{i,0}| + \gamma X_{i,0} + \epsilon_{i,+1},$$

where i represents firm i, subscript $+1$ means one-day after earning annoucement, and 0 means the earning annoucement day. We apply three $|\overline{SUE}_{i,0}|$s: raw earning surprise scaled by price, firm size and earning volatility, respectively. The control variables are the same with those in regression 1. The only different is that we calculate these variables on the earning annoucement day, for instance, analyst forecast dispersion is the standard deviation of analyst earning forecast within 90 days before the true earning is reported. Option and stock bid-ask spread is the bid-ask spread calculated via trading information on earning annoucement day. Option and stock trading volumes are the one in earning annoucement day.... In order to estimate β, we use pooled OLS and adjust the standard error by two-way cluster in firm and annoucement year.

The patterns in Table 10, 11, 12 are consistent with our earlier regressions. Larger earning surprise magnitude, no matter the news itself is good or bad, will lead to increasing implied volatility in following day right after earnings annoucement day, after controlling firm characteristics, heterogeneous belief proxy and other variables related to asset liquidity and informed trading.

6 Robustness Check

Large earning surprise sometimes is also linked with large fundamental volatility, such as earning and cash flow volatility. To ease such concernslarger earning surprise magnitude also generates higher firm default probability and bond returns. , we add three changes for our basic regression,

$$\begin{aligned} \frac{IV_{i,t+1} - IV_{i,t}}{IV_{i,t}} &= \alpha + \rho_1 IV_{i,t} + \rho_2 CashVol_{i,t} + \beta|\overline{SUE}_{i,t}| + \gamma X_{i,t} + \epsilon_{i,t+1}, \\ \frac{RV_{i,t+1} - RV_{i,t}}{RV_{i,t}} &= \alpha + \rho_1 RV_{i,t} + \rho_2 CashVol_{i,t} + \beta|\overline{SUE}_{i,t}| + \gamma X_{i,t} + \epsilon_{i,t+1}. \end{aligned} \tag{3}$$

First of all, we consider the percentage change of implied volatility. Secondly, except past volatility, we add earning volatility calculated using past three year's quarterly EPSX (Earnings Per Share (Basic) Excluding Extraordinary Items) as a control. Moreover, we use alternative earning surprise measures. As motivated in earlier section, our earning surprise in main regression is scaled by stock price, here, as robustness check, the raw earning surprise is scaled by firm size and earning volatility. Table 13, Table 14 and Table 15 indicate that our results are quite robust to different regressions and different definitions of earning surprise. The magnitue of earning surprise positively predict future implied volatility, but not implied volatility slope.

Since in the regression 1, we use the same earning surprise within each quarter, as another robustness check, the next month implied volatility just after earning annoucement is studied. We use the same regression framework as regression 3. Our results still hold: The magnitue of earning surprise positively predict future implied volatility, but not implied volatility slope.

In our main test, implied volatility of ATM option with 30 days time to maturity is used. As a robustness check, we used ATM option implied volatility with time to maturity of 60, 90, 122, 152 days. Using different time-to-maturity, our results is still consistent with our hypothesis. Larger absolute earnings surprise will increase the realized and implied volatility. In addition, the summary statistics shows that in our sample, month realized and implied variance can be larger than 100%. To ease the conern that our results are driven by the firms with extremely high volatility, we run the regression with constraints that realized and implied variance are less than 100%. In such sample, our results still holds. Because robustness results are quite the same, we do not show them all in the paper. But the regression results are available upon request.

7 Conclusion

Common wisdom related to investor learning behavior suggests that learning is able to decrease uncertainty. In the paper, we take a new and different angle about investor learning behavior and uncertainty about future economic condition. Motivated by Veronesi (1999) and other models, we conjugate that suppose realized signal deviating sufficiently from expected values, investors may revise their beliefs significantly and uncertainty towards future will increase. Using earning surprise as a measure of deviation between realized and expected signals, we study its long-term effect on equity implied volatility. Our results suggest that, larger earning surprise magnitude, no matter the news itself is good or bad, will lead to increasing implied volatility in following months, after controlling firm characteristics, heterogeneous belief proxy and other variables related to asset liquidity and informed trading. Moreover, we also find the same pattern for implied volatility change one day after earnings annoucement.

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Table 1: **Summary Statistics**

Summary statistics for variables used in the paper. TotalVS is the total variance premium for individual stocks. IdioVS is variance premium for idiosyncratic variance of individual stocks. RV is monthly total realized variance. IV is monthly implied variance. Beta is market beta. NumAna is logarithm of the number of analysts coverage the stock. DISP is analyst forecast dispersion. SIZE is firm size. MTB is market-to-book ratio. LEV is market leverage ratio. IOR is institutional ownership ratio. P/C is ratio of monthly trading volume of put and call option. SBAS is average of monthly closing bid-ask spread for stocks. DBAS is average of monthly closing bid-ask spread for options. O/S is monthly option trading volume divided by monthly stock trading volume. DIB is change of institutional ownership breadth. IC is institutional ownership concentration. The sample period is from January, 1996 to December, 2012, trimmed by 1%.

	RV	IV	RET	DFPob	CS	VS	SUE	BETA
min	0.0099	0.0253	-0.3824	0.0000	0.1806	-0.7652	-0.0393	0.1900
mean	0.1656	0.2258	0.0082	0.1170	3.2208	0.0601	0.0006	1.1561
sd	0.1930	0.1921	0.1173	0.1510	3.0858	0.1283	0.0047	0.4883
max	1.8015	1.5607	0.4415	0.6425	27.8710	0.7374	0.0253	2.8600
	SIZE	MTB	LEV	SBAS	DBAS	P/C	O/S	DISP
min	3.8218	0.1749	0.0000	0.0002	0.1632	0.0000	0.0561	0.0000
mean	7.4787	1.7654	0.2072	0.0043	0.5348	0.7347	6.5342	0.0053
sd	1.6504	1.3931	0.2068	0.0062	0.2084	0.8221	7.8395	0.0095
max	12.2882	9.9283	0.9906	0.0396	1.3182	7.1000	53.6955	0.1208

Table 2: **Fama-Mecbeth Regression: Earning Surprise and Volatility**

Fama-Macbeth cross-section regression for effect of earnings surprise on realized, implied volatility,

$$\{RV_{i,t+1}, IV_{i,t+1}\} = \alpha + \rho\{RV_{i,t}, IV_{i,t}\} + \beta|SUE_{i,t}| + \gamma X_{i,t} + \epsilon_{i,t+1},$$

where X_t is the vector of control variables, including monthly average closing bid-ask spread (SBAS) as a measure of liquidity for underlying equities, monthly average closing bid-ask spread (DBAS) as a measure of derivative liquidity, the ratio of monthly trading volume of options and stocks (O/S), leverage raio (LEV), firm size (SIZE), market to book ratio (MTB), ratio of monthly put volume to monthly call volume (P/C), analyst forecast dispersion (DISP), and 1-month past return (RET). The sample period is from January, 1996 to December, 2012. The time window is month. Neway-West adjustment with 12 lags is used for calculate standard errors. Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 '' 1. ρ is always positive and significant, therefore, to save space, ρ is not reported. Δ measures the square root of change for dependent variable, when independent variable has one standard deviation change.

	SBAS	DBAS	LEV	SIZE	MTB	P/C	O/S	DISP	RET	SUE
RV	9.5182**	−0.0276*	0.0366***	−0.0229***	0.0008	−0.0044***	0.0012***	1.1993***	−0.1035***	1.6008***
	(2.8936)	(0.0120)	(0.0096)	(0.0023)	(0.0014)	(0.0011)	(0.0002)	(0.1403)	(0.0168)	(0.1990)
Δ	24.3891%	7.6323%	8.7661%	19.4707%	3.4293%	6.0090%	9.5069%	10.9685%	11.0926%	9.1057%
IV	4.6431**	0.0009	0.0125***	−0.0077***	0.0003	−0.0017***	0.0005***	0.4097***	−0.0678***	0.5590***
	(1.4436)	(0.0043)	(0.0033)	(0.0006)	(0.0004)	(0.0004)	(0.0001)	(0.0581)	(0.0101)	(0.0559)
Δ	17.0342%	1.3509%	5.1271%	11.2893%	2.1058%	3.7835%	5.9855%	6.4111%	8.9752%	5.3807%

Table 3: **Fama-Mecbeth Regression: Earning Surprise and Implied Volatility**

Fama-Macbeth cross-section regression for effect of earnings surprise on realized and implied volatility, when $SUE_{i,t} > 0$,

$$\{IVC_{i,t+1}, IVP_{i,t+1}, IVPC_{i,t+1}\} = \alpha + \rho\{IVC_{i,t}, IVP_{i,t}, IVPC_{i,t}\} + \beta SUE_{i,t} + \gamma X_{i,t} + \epsilon_{i,t+1},$$

where X_t is the vector of control variables, including monthly average closing bid-ask spread (SBAS) as a measure of liquidity for underlying equities, monthly average closing bid-ask spread (DBAS) as a measure of derivative liquidity, the ratio of monthly trading volume of options and stocks (O/S), leverage raio (LEV), firm size (SIZE), market to book ratio (MTB), ratio of monthly put volume to monthly call volume (P/C), analyst forecast dispersion (DISP), and 1-month past return (RET). Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

	SBAS	DBAS	LEV	SIZE	MTB	P/C	O/S	DISP	RET	SUE
IVC	3.7672*	0.0122*	0.0080*	−0.0101***	0.0002	−0.0013**	0.0004***	0.3568***	−0.0632***	1.5361***
	(1.5435)	(0.0056)	(0.0031)	(0.0007)	(0.0005)	(0.0004)	(0.0001)	(0.0593)	(0.0090)	(0.1159)
Δ	2.1999%	0.2463%	0.1618%	1.6651%	0.0242%	0.1034%	0.3508%	0.2949%	0.7354%	0.5176%
IVP	3.9100*	0.0120*	0.0093**	−0.0098***	0.0003	−0.0016***	0.0004***	0.3629***	−0.0754***	1.4014***
	(1.5965)	(0.0055)	(0.0031)	(0.0008)	(0.0004)	(0.0004)	(0.0001)	(0.0449)	(0.0084)	(0.1261)
Δ	2.2834%	0.2434%	0.1890%	1.6088%	0.0393%	0.1246%	0.3299%	0.2999%	0.8767%	0.4722%
IVPC	−0.6232*	0.0056·	−0.0076***	0.0008***	−0.0004***	−0.0008**	−0.0001*	0.0042	-0.0005	0.0396
	(0.2705)	(0.0033)	(0.0009)	(0.0001)	(0.0001)	(0.0003)	(0.0000)	(0.0327)	(0.0047)	(0.0790)
Δ	0.3639%	0.1134%	0.1543%	0.1303%	0.0509%	0.0642%	0.0771%	0.0035%	0.0057%	0.0134%

Table 4: **Fama-Mecbeth Regression: Earning Surprise and Implied Volatility**

Fama-Macbeth cross-section regression for effect of earnings surprise on realized and implied volatility, when $SUE_{i,t} < 0$,

$$\{IVC_{i,t+1}, IVP_{i,t+1}, IVPC_{i,t+1}\} = \alpha + \rho\{IVC_{i,t}, IVP_{i,t}, IVPC_{i,t}\} + \beta SUE_{i,t} + \gamma X_{i,t} + \epsilon_{i,t+1},$$

where X_t is the vector of control variables, including monthly average closing bid-ask spread (SBAS) as a measure of liquidity for underlying equities, monthly average closing bid-ask spread (DBAS) as a measure of derivative liquidity, the ratio of monthly trading volume of options and stocks (O/S), leverage raio (LEV), firm size (SIZE), market to book ratio (MTB), ratio of monthly put volume to monthly call volume (P/C), analyst forecast dispersion (DISP), and 1-month past return (RET). Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 '' 1.

	SBAS	DBAS	LEV	SIZE	MTB	P/C	O/S	DISP	RET	SUE
IVC	4.1674**	0.0340***	0.0071·	−0.0078***	0.0012**	−0.0041***	0.0005***	0.2753***	−0.0607***	−0.9130***
	(1.3457)	(0.0067)	(0.0041)	(0.0007)	(0.0004)	(0.0011)	(0.0001)	(0.0597)	(0.0139)	(0.2548)
Δ	2.7363%	0.7176%	0.1546%	1.2866%	0.1507%	0.3599%	0.4271%	0.3427%	0.7370%	0.5186%
IVP	4.2494***	0.0337***	0.0085*	−0.0074***	0.0013**	−0.0040***	0.0005***	0.3142***	−0.0693***	−0.8729***
	(1.2647)	(0.0064)	(0.0039)	(0.0007)	(0.0004)	(0.0009)	(0.0001)	(0.0531)	(0.0118)	(0.2215)
Δ	2.7901%	0.7125%	0.1856%	1.2144%	0.1699%	0.3542%	0.4305%	0.3911%	0.8411%	0.4958%
IVPC	−0.6257*	0.0071·	−0.0065***	0.0005*	-0.0002	−0.0012·	−0.0001*	-0.0176	-0.0059	0.0092
	(0.2981)	(0.0038)	(0.0012)	(0.0002)	(0.0003)	(0.00006)	(0.0001)	(0.0273)	(0.0056)	(0.0735)
Δ	0.4108%	0.1496%	0.1409%	0.0758%	0.0237%	0.1097%	0.1096%	0.0220%	0.0715%	0.0052%

Table 5: **Fama-Mecbeth Regression: Earning Surprise and Distance to Default**

Fama-Macbeth cross-section regression for effect of earnings surprise on Merton's distance to default,

$$\pi_{i,t+1}^{merton} = \alpha + \beta SUE_{i,t} + \gamma X_{i,t} + \epsilon_{i,t+1},$$

where $\pi_{i,t+1}^{merton}$ is distance to default calculated by Merton (1974) structure model. X_t is the vector of control variables, including monthly implied variance (IV), volatilty skew based option with maturity 30 days (SKEW), leverage raio (LEV), firm size (SIZE), market to book ratio (MTB), analyst forecast dispersion (DISP), S&P 500 firm credit rating (RATE), and past month stock return (RET). Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 " 1..

	IV	LEV	SIZE	MTB	SUE	DISP	RATE	SKEW	RET
$\|SUE\|$	0.4118***	0.1800***	0.0083***	−0.0147***	1.2795***	0.5336***	0.0014	0.0834	0.6270***
	(0.0292)	(0.0192)	(0.0015)	(0.0042)	(0.1749)	(0.1079)	(0.0013)	(0.0725)	(0.0218)
Δ	6.5883%	3.4974%	1.1267%	1.1910%	0.6937%	0.4936%	0.4658%	0.1019%	11.8133%
$SUE > 0$	0.3880***	0.1746***	0.0085***	−0.0132***	1.4089***	0.7244***	0.0016	0.0985	0.6082***
	(0.0311)	(0.0190)	(0.0018)	(0.0037)	(0.2451)	(0.1159)	(0.0014)	(0.0980)	(0.0186)
Δ	5.9824%	3.3197%	1.1602%	1.0644%	0.4521%	0.5665%	0.5102%	0.1159%	11.1802%
$SUE < 0$	0.4440***	0.1671***	0.0085***	−0.0201***	−1.8226***	0.1178	0.0022.	0.0012	0.6598***
	(0.0271)	(0.0180)	(0.0016)	(0.0055)	(0.2702)	(0.1540)	(0.0013)	(0.0870)	(0.0192)
Δ	7.5057%	3.3006%	1.1196%	1.4793%	1.1267%	0.1345%	0.7146%	0.0015%	12.8238%

Table 6: **Fama-Mecbeth Regression: Earning Surprise and Credit Spreads**

Fama-Macbeth cross-section regression for effect of earnings surprise on Merton's distance to default,

$$cs_{i,t+1} = \alpha + \beta SUE_{i,t} + \gamma X_{i,t} + \epsilon_{i,t+1},$$

where $\pi_{i,t+1}^{merton}$ is distance to default calculated by Merton (1974) structure model. X_t is the vector of control variables, including monthly implied variance (IV), volatilty skew based option with maturity 30 days (SKEW), leverage raio (LEV), firm size (SIZE), market to book ratio (MTB), analyst forecast dispersion (DISP), S&P 500 firm credit rating (RATE), and past month stock return (RET). Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 " 1..

	IV	LEV	SIZE	MTB	SUE	DISP	SKEW	RATE	RET
$\|SUE\|$	3.0200***	0.7647***	−0.0474.	0.0573	15.0451**	6.8142	-0.4342	0.2096***	-0.0978
	(0.3128)	(0.1423)	(0.0271)	(0.0503)	(4.8444)	(4.9084)	(1.3272)	(0.0233)	(0.1525)
Δ	0.4988%	0.1418%	0.0630%	0.0363%	0.1130%	0.0837%	0.0059%	0.6507%	0.0092%
$SUE > 0$	2.6700***	0.6727***	−0.0593*	0.1006*	5.9551	6.1691	0.9057	0.2071***	-0.1002
	(0.3854)	(0.1473)	(0.0281)	(0.0468)	(11.1511)	(5.2077)	(2.7256)	(0.0240)	(0.2188)
Δ	0.3872%	0.1214%	0.0791%	0.0644%	0.0263%	0.0475%	0.0106%	0.6246%	0.0088%
$SUE < 0$	4.2203***	1.1814***	-0.0228	-0.0762	-10.4168	3.2844	-0.7489	0.2513***	-0.2725
	(0.4025)	(0.2051)	(0.0491)	(0.1403)	(7.8276)	(4.3161)	(1.6919)	(0.0278)	(0.1857)
Δ	0.9071%	0.2303%	0.0295%	0.0434%	0.2416%	0.0969%	0.0138%	0.7793%	0.0308%

Table 7: **Fama-Mecbeth Regression: Earning Surprise and Implied Variance, subsample results**

Fama-Macbeth cross-section regression for effect of earnings surprise on implied variance, subsamples are divided by **idiosyncratic volatility**,

$$IV_{i,t+1} = \alpha + \rho IV_{i,t} + \beta |SUE_{i,t}| + \gamma X_{i,t} + \epsilon_{i,t+1},$$

where X_t is the vector of control variables, including monthly average closing bid-ask spread (SBAS) as a measure of liquidity for underlying equities, monthly average closing bid-ask spread (DBAS) as a measure of derivative liquidity, the ratio of monthly trading volume of options and stocks (O/S), leverage raio (LEV), firm size (SIZE), market to book ratio (MTB), ratio of monthly put volume to monthly call volume (P/C), analyst forecast dispersion (DISP), and 1-month past return (RET). The sample period is from January, 1996 to December, 2012. The time window is month. Neway-West adjustment with 12 lags is used for calculate standard errors. Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 '' 1. ρ is always positive and significant, therefore, to save space, ρ is not reported. Δ measures the square root of change for dependent variable, when independent variable has one standard deviation change.

	SBAS	DBAS	LEV	SIZE	MTB	P/C	O/S	DISP	RET	SUE
low	0.8360*	0.0007	0.0023	−0.0016***	-0.0002	0.0006**	0.0002**	0.2157***	−0.0278***	0.1976**
	(0.3312)	(0.0018)	(0.0017)	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0558)	(0.0075)	(0.0830)
Δ	6.7725%	1.1885%	2.1106%	4.6466%	1.6057%	2.1956%	3.3459%	3.5018%	4.7487%	2.3632%
median	0.8946	0.0136.	-0.0028	0.0007	0.0009*	−0.0010.	0.0003*	-0.0423	−0.0597***	0.4930***
	(0.6692)	(0.0071)	(0.0145)	(0.0050)	(0.0004)	(0.0006)	(0.0001)	(0.2594)	(0.0119)	(0.0994)
Δ	7.7655%	5.2779%	2.4087%	3.0961%	3.3952%	2.9343%	4.6877%	1.8720%	8.3188%	4.5642%
high	5.3321**	0.0195**	0.0197***	−0.0071***	0.0013**	−0.0042***	0.0002*	0.4336***	−0.0875***	0.6035***
	(1.8468)	(0.0067)	(0.0048)	(0.0009)	(0.0004)	(0.0009)	(0.0001)	(0.0635)	(0.0108)	(0.1220)
Δ	18.5025%	6.5675%	6.6572%	9.7585%	4.5985%	5.5764%	4.5612%	7.8164%	11.6003%	6.6813%

Table 8: **Fama-Mecbeth Regression: Earning Surprise and Implied Variance, subsample results**

Fama-Macbeth cross-section regression for effect of earnings surprise on implied variance, subsamples are divided by **firm size**,

$$IV_{i,t+1} = \alpha + \rho IV_{i,t} + \beta|SUE_{i,t}| + \gamma X_{i,t} + \epsilon_{i,t+1},$$

where X_t is the vector of control variables, including monthly average closing bid-ask spread (SBAS) as a measure of liquidity for underlying equities, monthly average closing bid-ask spread (DBAS) as a measure of derivative liquidity, the ratio of monthly trading volume of options and stocks (O/S), leverage raio (LEV), firm size (SIZE), market to book ratio (MTB), ratio of monthly put volume to monthly call volume (P/C), analyst forecast dispersion (DISP), and 1-month past return (RET). The sample period is from January, 1996 to December, 2012. The time window is month. Neway-West adjustment with 12 lags is used for calculate standard errors. Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 '' 1. ρ is always positive and significant, therefore, to save space, ρ is not reported. Δ measures the square root of change for dependent variable, when independent variable has one standard deviation change.

	SBAS	DBAS	LEV	SIZE	MTB	P/C	O/S	DISP	RET	SUE
low	5.1241**	0.0129*	0.0177**	−0.0164***	0.0001	−0.0033***	0.0002*	0.4139***	−0.0772***	0.7442***
	(1.8145)	(0.0064)	(0.0066)	(0.0013)	(0.0004)	(0.0006)	(0.0001)	(0.0935)	(0.0091)	(0.1240)
Δ	17.6103%	5.3884%	4.8413%	10.7674%	1.4079%	5.3323%	3.4773%	6.6967%	10.4183%	6.5756%
media	1.5853*	0.0054	0.0084***	−0.0072***	-0.0006	−0.0010**	0.0005***	0.2953***	−0.0574***	0.3926***
	(0.6389)	(0.0034)	(0.0024)	(0.0010)	(0.0008)	(0.0003)	(0.0001)	(0.0622)	(0.0111)	(0.0938)
Δ	10.3905%	3.3357%	3.9709%	5.9914%	2.5843%	2.8738%	6.1468%	5.3945%	8.1721%	4.4514%
high	2.8520**	-0.0022	0.0073*	−0.0025***	-0.0006	0.0002	0.0003***	0.3246***	−0.0498***	0.4586**
	(0.8708)	(0.0023)	(0.0030)	(0.0003)	(0.0004)	(0.0005)	(0.0001)	(0.0649)	(0.0125)	(0.1653)
Δ	12.8435%	2.0214%	4.0450%	4.7066%	2.2860%	1.2140%	5.1214%	5.5323%	6.9167%	4.6174%

Table 9: **Fama-Mecbeth Regression: Earning Surprise and Implied Variance, subsample results**

Fama-Macbeth cross-section regression for effect of earnings surprise on implied variance, subsamples are divided by **firm age**,

$$IV_{i,t+1} = \alpha + \rho IV_{i,t} + \beta|SUE_{i,t}| + \gamma X_{i,t} + \epsilon_{i,t+1},$$

where X_t is the vector of control variables, including monthly average closing bid-ask spread (SBAS) as a measure of liquidity for underlying equities, monthly average closing bid-ask spread (DBAS) as a measure of derivative liquidity, the ratio of monthly trading volume of options and stocks (O/S), leverage raio (LEV), firm size (SIZE), market to book ratio (MTB), ratio of monthly put volume to monthly call volume (P/C), analyst forecast dispersion (DISP), and 1-month past return (RET). The sample period is from January, 1996 to December, 2012. The time window is month. Neway-West adjustment with 12 lags is used for calculate standard errors. Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 '' 1. ρ is always positive and significant, therefore, to save space, ρ is not reported. Δ measures the square root of change for dependent variable, when independent variable has one standard deviation change.

	SBAS	DBAS	LEV	SIZE	MTB	P/C	O/S	DISP	RET	SUE
low	4.6582**	0.0065	0.0097*	−0.0094***	0.0007	−0.0020***	0.0002*	0.4498***	−0.0838***	0.7557***
	(1.5040)	(0.0063)	(0.0042)	(0.0008)	(0.0007)	(0.0005)	(0.0001)	(0.0850)	(0.0118)	(0.1760)
Δ	16.8883%	3.7577%	4.5447%	11.6276%	3.4053%	4.1112%	4.0488%	7.0661%	10.5608%	6.5639%
media	5.0579**	0.0042	0.0100**	−0.0065***	-0.0004	−0.0020***	0.0006***	0.3169***	−0.0639***	0.5880***
	(1.8854)	(0.0050)	(0.0035)	(0.0006)	(0.0005)	(0.0003)	(0.0001)	(0.0491)	(0.0098)	(0.0845)
Δ	18.1286%	2.9775%	4.6154%	9.8925%	2.3315%	4.1468%	6.6629%	5.6942%	8.8032%	5.5555%
high	3.1026***	0.0023	0.0090**	−0.0036***	-0.0002	-0.0005	0.0004***	0.3947***	−0.0434***	0.3519***
	(0.9154)	(0.0030)	(0.0029)	(0.0004)	(0.0004)	(0.0003)	(0.0001)	(0.0844)	(0.0102)	(0.0667)
Δ	13.7691%	2.1418%	4.1996%	7.2924%	1.4237%	1.9436%	5.2532%	5.8290%	6.6126%	3.9923%

Table 10: **Short-Term Effect: Earning Surprise and Implied Volatility**

Fama-Macbeth cross-section regression for effect of earnings surprise on realized and implied volatility, $SUE_{i,t}$ is calculated as raw earning surprise **scaled by stock price**,

$$\Delta\{RV_{i,+1}, IV_{+1}, IVC_{i,+1}, IVP_{i,+1}, IVPC_{i,+1}\} = \alpha + \rho_1\{RV_{i,0}, IV_{i,0}, IVC_{i,0}, IVP_{i,0}, IVPC_{i,0}\} + \rho_2 Vol_{EPSX} + \beta\overline{SUE}_{i,0} + \gamma X_{i,0} + \epsilon_{i,+1},$$

where dependent variables are percentage change of realized volatility, implied volatility, put & call implied volatility, and implied volatility slope. X_t is the vector of control variables, including monthly average closing bid-ask spread (SBAS) as a measure of liquidity for underlying equities, monthly average closing bid-ask spread (DBAS) as a measure of derivative liquidity, the ratio of monthly trading volume of options and stocks (O/S), leverage raio (LEV), firm size (SIZE), market to book ratio (MTB), ratio of monthly put volume to monthly call volume (P/C), analyst forecast dispersion (DISP), and 1-month past return (RET). Due to limited spcae, the coefficients ρ_1 and ρ_2 are omitted. Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 " 1.

	SBAS	DBAS	LEV	SIZE	MTB	P/C	O/S	DISP	RET	SUE
RV	1.1294·	-0.0555***	0.0468**	-0.0213***	0.0027	0.0010	1.4484	0.0217**	-0.2569***	1.6842*
	(0.5880)	(0.0142)	(0.0162)	(0.0022)	(0.0036)	(0.0016)	(1.1673)	(0.0066)	(0.0569)	(0.8071)
IV	1.1806***	-0.0225**	0.0306***	-0.0032**	-0.0004	-0.0006***	-0.6282	0.0036*	-0.0215	1.0121***
	(0.1786)	(0.0084)	(0.0050)	(0.0011)	(0.0008)	(0.0002)	(0.5782)	(0.0017)	(0.0137)	(0.2129)
IVC	1.2088***	-0.0082	0.0286***	-0.0031*	-0.0004	-0.0005·	-0.7109	0.0039	0.0966***	0.9386***
	(0.2122)	(0.0092)	(0.0054)	(0.0013)	(0.0007)	(0.0003)	(0.5779)	(0.0025)	(0.0126)	(0.2121)
IVP	1.2621***	-0.0136·	0.0302***	-0.0029**	-0.0004	-0.0006*	-0.4766	0.0027*	-0.1341***	1.0134***
	(0.1876)	(0.0082)	(0.0049)	(0.0010)	(0.0008)	(0.0003)	(0.5680)	(0.0012)	(0.0289)	(0.2230)
IVPC	0.0527	0.0049	0.0070*	0.0010	0.0009	0.0003	0.4373**	-0.0016	-0.0431***	0.1610
	(0.1056)	(0.0039)	(0.0035)	(0.0006)	(0.0008)	(0.0003)	(0.1631)	(0.0015)	(0.0119)	(0.1587)

Table 11: **Short-Term Effect: Earning Surprise and Implied Volatility**

Fama-Macbeth cross-section regression for effect of earnings surprise on realized and implied volatility, $SUE_{i,t}$ is calculated as raw earning surprise **scaled by firm size**,

$$\Delta\{RV_{i,t+1}, IV_{i+1}, IVC_{i,t+1}, IVP_{i,t+1}, IVPC_{i,t+1}\} = \alpha+\rho_1\{RV_{i,t}, RV_{i,t}, IVC_{i,t}, IVP_{i,t}, IVPC_{i,t}\}+\rho_2 Vol_{EPSX}+\beta\overline{SUE}_{i,t}+\gamma X_{i,t}+\epsilon_{i,t+1},$$

where dependent variables are percentage change of realized volatility, implied volatility, put & call implied volatility, and implied volatility slope. X_t is the vector of control variables, including monthly average closing bid-ask spread (SBAS) as a measure of liquidity for underlying equities, monthly average closing bid-ask spread (DBAS) as a measure of derivative liquidity, the ratio of monthly trading volume of options and stocks (O/S), leverage raio (LEV), firm size (SIZE), market to book ratio (MTB), ratio of monthly put volume to monthly call volume (P/C), analyst forecast dispersion (DISP), and 1-month past return (RET). Due to limited spcae, the coefficients ρ_1 and ρ_2 are omitted. Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 '' 1.

	SBAS	DBAS	LEV	SIZE	MTB	P/C	O/S	DISP	RET	SUE
RV	1.0400·	-0.0531***	0.0579***	-0.0224***	0.0021	0.0010	1.4934	0.0270***	-0.2498***	-0.4390
	(0.5823)	(0.0141)	(0.0162)	(0.0023)	(0.0035)	(0.0015)	(1.1885)	(0.0065)	(0.0569)	(0.3732)
IV	1.1735***	-0.0195*	0.0344***	-0.0032**	-0.0006	-0.0006***	-0.6345	0.0049**	-0.0205	0.2144**
	(0.1735)	(0.0085)	(0.0051)	(0.0011)	(0.0007)	(0.0002)	(0.5816)	(0.0018)	(0.0138)	(0.0728)
IVC	1.2055***	-0.0054	0.0320***	-0.0031*	-0.0005	-0.0005·	-0.7183	0.0050·	0.0974***	0.2229**
	(0.2093)	(0.0092)	(0.0055)	(0.0013)	(0.0007)	(0.0003)	(0.5826)	(0.0027)	(0.0128)	(0.0755)
IVP	1.2585***	-0.0106	0.0339***	-0.0029**	-0.0005	-0.0007*	-0.4846	0.0039**	-0.1333***	0.2403**
	(0.1832)	(0.0083)	(0.0051)	(0.0010)	(0.0008)	(0.0003)	(0.5719)	(0.0013)	(0.0290)	(0.0768)
IVPC	0.0605	0.0053	0.0076*	0.0009	0.0009	0.0003	0.4330**	-0.0016	-0.0434***	0.0833
	(0.1062)	(0.0038)	(0.0037)	(0.0006)	(0.0008)	(0.0003)	(0.1626)	(0.0015)	(0.0119)	(0.0633)

Table 12: **Short-Term Effect: Earning Surprise and Implied Volatility**

Fama-Macbeth cross-section regression for effect of earnings surprise on realized and implied volatility, $SUE_{i,t}$ is calculated as raw earning surprise **scaled by firm earning volatility**,

$$\Delta\{RV_{i,t+1}, IV_{i+1}, IVC_{i,t+1}, IVP_{i,t+1}, IVPC_{i,t+1}\} = \alpha+\rho_1\{RV_{i,t}, RV_{i,t}, IVC_{i,t}, IVP_{i,t}, IVPC_{i,t}\}+\rho_2 Vol_{EPSX}+\beta\overline{SUE}_{i,t}+\gamma X_{i,t}+\epsilon_{i,t+1},$$

where dependent variables are percentage change of realized volatility, implied volatility, put & call implied volatility, and implied volatility slope. X_t is the vector of control variables, including monthly average closing bid-ask spread (SBAS) as a measure of liquidity for underlying equities, monthly average closing bid-ask spread (DBAS) as a measure of derivative liquidity, the ratio of monthly trading volume of options and stocks (O/S), leverage raio (LEV), firm size (SIZE), market to book ratio (MTB), ratio of monthly put volume to monthly call volume (P/C), analyst forecast dispersion (DISP), and 1-month past return (RET). Due to limited spcae, the coefficients ρ_1 and ρ_2 are omitted. Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 '' 1.

	SBAS	DBAS	LEV	SIZE	MTB	P/C	O/S	DISP	RET	SUE
RV	1.0572·	-0.0517***	0.0569***	-0.0222***	0.0022	0.0009	1.4818	0.0262***	-0.2501***	-0.0128
	(0.5875)	(0.0142)	(0.0166)	(0.0024)	(0.0035)	(0.0015)	(1.1825)	(0.0064)	(0.0572)	(0.0149)
IV	1.1597***	-0.0200	0.0350***	-0.0033**	-0.0007	-0.0006***	-0.6270	0.0054**	-0.0201	0.0047·
	(0.1722)	(0.0140)	(0.0050)	(0.0011)	(0.0008)	(0.0002)	(0.5774)	(0.0018)	(0.0140)	(0.0026)
IVC	1.1597***	-0.0200	0.0350***	-0.0033*	-0.0007	-0.0006·	-0.6270	0.0054*	-0.0201***	0.0047·
	(0.1722)	(0.0084)	(0.0050)	(0.0011)	(0.0008)	(0.0002)	(0.5774)	(0.0018)	(0.0140)	(0.0026)
IVP	1.2443***	-0.0112	0.0345***	-0.0030**	-0.0006	-0.0007*	-0.4767	0.0045***	-0.1329***	0.0057*
	(0.1829)	(0.0082)	(0.0051)	(0.0010)	(0.0008)	(0.0003)	(0.5684)	(0.0012)	(0.0292)	(0.0028)
IVPC	0.0591	0.0050	0.0077*	0.0009	0.0008	0.0003	0.4343**	-0.0014	-0.0435***	0.0030
	(0.1074)	(0.0038)	(0.0036)	(0.0006)	(0.0006)	(0.0003)	(0.1615)	(0.0016)	(0.0118)	(0.0024)

Table 13: **Robustness Check: Earning Surprise and Implied Volatility**

Fama-Macbeth cross-section regression for effect of earnings surprise on realized and implied volatility, $SUE_{i,t}$ is calculated as raw earning surprise **scaled by stock price**,

$$\Delta\{RV_{i,t+1}, IV_{i+1}, IVC_{i,t+1}, IVP_{i,t+1}, IVPC_{i,t+1}\} = \alpha + \rho_1\{RV_{i,t}, RV_{i,t}, IVC_{i,t}, IVP_{i,t}, IVPC_{i,t}\} + \rho_2 Vol_{EPSX} + \beta\overline{SUE}_{i,t} + \gamma X_{i,t} + \epsilon_{i,t+1},$$

where dependent variables are percentage change of realized volatility, implied volatility, put & call implied volatility, and implied volatility slope. X_t is the vector of control variables, including monthly average closing bid-ask spread (SBAS) as a measure of liquidity for underlying equities, monthly average closing bid-ask spread (DBAS) as a measure of derivative liquidity, the ratio of monthly trading volume of options and stocks (O/S), leverage raio (LEV), firm size (SIZE), market to book ratio (MTB), ratio of monthly put volume to monthly call volume (P/C), analyst forecast dispersion (DISP), and 1-month past return (RET). Due to limited spcae, the coefficients ρ_1 and ρ_2 are omitted. Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 " 1.

	SBAS	DBAS	LEV	SIZE	MTB	P/C	O/S	DISP	RET	SUE
RV	0.1193***	0.0056	0.0314	0.0508***	0.0326***	0.3323***	0.0075***	0.0129	-0.6418***	2.3337***
	(0.0088)	(0.0064)	(0.0304)	(0.0060)	(0.0032)	(0.0883)	(0.0022)	(0.0097)	(0.0490)	(0.6418)
IV	0.0034**	0.0006	0.0078**	0.0031***	0.0038***	0.0010	-0.0005*	-0.0008	-0.0825***	0.3069***
	(0.0011)	(0.0004)	(0.0027)	(0.0009)	(0.0005)	(0.0078)	(0.0002)	(0.0008)	(0.0102)	(0.0763)
IVC	0.0001	0.0029**	0.0047·	0.0026**	0.0034***	0.2053***	-0.0009***	-0.0005	-0.0834***	0.3023***
	(0.0004)	(0.0011)	(0.0028)	(0.0009)	(0.0005)	(0.0134)	(0.0002)	(0.0008)	(0.0121)	(0.0752)
IVP	0.0011**	0.0040***	0.0107***	0.0038***	0.0042***	-0.1945***	-0.0001	-0.0009	-0.0826***	0.2985***
	(0.0004)	(0.0012)	(0.0029)	(0.0009)	(0.0005)	(0.0194)	(0.0003)	(0.0008)	(0.0089)	(0.0862)
IVPC	-0.0010**	-0.0007*	0.0055***	0.0008*	0.0005***	-0.3732***	0.0009***	-0.0002	0.0016	-0.0093
	(0.0003)	(0.0003)	(0.0013)	(0.0003)	(0.0002)	(0.0304)	(0.0001)	(0.0003)	(0.0059)	(0.0372)

Table 14: **Robustness Check: Earning Surprise and Implied Volatility**

Fama-Macbeth cross-section regression for effect of earnings surprise on realized and implied volatility, $SUE_{i,t}$ is calculated as raw earning surprise **scaled by firm size**,

$\Delta\{RV_{i,t+1}, IV_{i+1}, IVC_{i,t+1}, IVP_{i,t+1}, IVPC_{i,t+1}\} = \alpha + \rho_1\{RV_{i,t}, RV_{i,t}, IVC_{i,t}, IVP_{i,t}, IVPC_{i,t}\} + \rho_2 Vol_{EPSX} + \beta\overline{SUE}_{i,t} + \gamma X_{i,t} + \epsilon_{i,t+1}$,

where dependent variables are percentage change of realized volatility, implied volatility, put & call implied volatility, and implied volatility slope. X_t is the vector of control variables, including monthly average closing bid-ask spread (SBAS) as a measure of liquidity for underlying equities, monthly average closing bid-ask spread (DBAS) as a measure of derivative liquidity, the ratio of monthly trading volume of options and stocks (O/S), leverage raio (LEV), firm size (SIZE), market to book ratio (MTB), ratio of monthly put volume to monthly call volume (P/C), analyst forecast dispersion (DISP), and 1-month past return (RET). Due to limited spcae, the coefficients ρ_1 and ρ_2 are omitted. Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 '' 1.

	SBAS	DBAS	LEV	SIZE	MTB	P/C	O/S	DISP	RET	SUE
RV	0.1197***	0.0049	0.0507	0.0484***	0.0317***	0.3313***	0.0077***	0.0194·	-0.6432***	0.5260·
	(0.0089)	(0.0064)	(0.0311)	(0.0060)	(0.0032)	(0.0873)	(0.0021)	(0.0099)	(0.0491)	(0.2830)
IV	0.0007·	0.0031**	0.0091**	0.0029***	0.0036***	0.0012	0.0005*	-0.0005	-0.0829***	0.1266***
	(0.0004)	(0.0011)	(0.0028)	(0.0009)	(0.0005)	(0.0078)	(0.0002)	(0.0008)	(0.0102)	(0.0315)
IVC	0.0001	0.0026*	0.0059*	0.0024**	0.0033***	0.2054***	0.0010***	-0.0003	-0.0837***	0.1298***
	(0.0004)	(0.0011)	(0.0029)	(0.0008)	(0.0005)	(0.0134)	(0.0002)	(0.0008)	(0.0121)	(0.0337)
IVP	0.0011**	0.0037**	0.0119***	0.0035***	0.0040***	-0.1943***	-0.0001	-0.0007	-0.0829***	0.1214***
	(0.0004)	(0.0012)	(0.0031)	(0.0009)	(0.0005)	(0.0194)	(0.0003)	(0.0008)	(0.0089)	(0.0314)
IVPC	0.0010**	0.0007*	0.0055***	0.0008*	0.0005**	-0.3732**	0.0009***	-0.0002	0.0016	-0.0058
	(0.0003)	(0.0003)	(0.0014)	(0.0003)	(0.0002)	(0.0304)	(0.0001)	(0.0003)	(0.0059)	(0.0104)

Table 15: **Robustness Check: Earning Surprise and Implied Volatility**

Fama-Macbeth cross-section regression for effect of earnings surprise on realized and implied volatility, $SUE_{i,t}$ is calculated as raw earning surprise **scaled by firm earning volatility**,

$\Delta\{RV_{i,t+1}, IV_{i+1}, IVC_{i,t+1}, IVP_{i,t+1}, IVPC_{i,t+1}\} = \alpha+\rho_1\{RV_{i,t}, RV_{i,t}, IVC_{i,t}, IVP_{i,t}, IVPC_{i,t}\}+\rho_2 Vol_{EPSX}+\beta\overline{SUE}_{i,t}+\gamma X_{i,t}+\epsilon_{i,t+1}$,

where dependent variables are percentage change of realized volatility, implied volatility, put & call implied volatility, and implied volatility slope. X_t is the vector of control variables, including monthly average closing bid-ask spread (SBAS) as a measure of liquidity for underlying equities, monthly average closing bid-ask spread (DBAS) as a measure of derivative liquidity, the ratio of monthly trading volume of options and stocks (O/S), leverage raio (LEV), firm size (SIZE), market to book ratio (MTB), ratio of monthly put volume to monthly call volume (P/C), analyst forecast dispersion (DISP), and 1-month past return (RET). Due to limited spcae, the coefficients ρ_1 and ρ_2 are omitted. Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 '' 1.

	SBAS	DBAS	LEV	SIZE	MTB	P/C	O/S	DISP	RET	SUE
RV	0.1193***	0.0051	0.0484	0.0485***	0.0318***	0.3313***	0.0077***	0.0192·	-0.6429***	0.0195·
	(0.0088)	(0.0064)	(0.0310)	(0.0060)	(0.0032)	(0.0871)	(0.0022)	(0.0101)	(0.0485)	(0.0100)
IV	0.0006	0.0031*	0.0092*	0.0029**	0.0036***	0.0014***	-0.0005***	-0.0004	-0.0829***	0.0052***
	(0.0004)	(0.0011)	(0.0028)	(0.0009)	(0.0005)	(0.0079)	(0.0002)	(0.0008)	(0.0102)	(0.0012)
IVC	0.0001	0.0027*	0.0061*	0.0023**	0.0032***	0.2058***	-0.0010***	-0.0002	-0.0837***	0.0053***
	(0.0004)	(0.0011)	(0.0028)	(0.0008)	(0.0005)	(0.0134)	(0.0002)	(0.0008)	(0.0121)	0.0013
IVP	0.0038**	0.0011**	0.0121***	0.0035***	0.0040***	-0.1941	-0.0001***	-0.0006	-0.0829***	0.0052***
	(0.0012)	(0.0004)	(0.0031)	(0.0009)	(0.0005)	(0.0195)	(0.0003)	(0.0008)	(0.0089)	(0.0012)
IVPC	0.0007*	0.0010**	0.0055***	0.0008*	0.0005**	-0.3733***	0.0009***	-0.0002	0.0016	0.00003
	(0.0003)	(0.0003)	(0.0014)	(0.0003)	(0.0002)	(0.0304)	(0.0001)	(0.0003)	(0.0059)	(0.0005)