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Arbitrage risk, investor sentiment and maximum daily returns

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ARBITRAGE RISK, INVESTOR SENTIMENT AND MAXIMUM DAILY RETURNS

by

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ABSTRACT

We test the cross-sectional relation between daily maximum return (MAX) and return in the following month for stocks with high and low idiosyncratic volatility. We use portfolio level analysis and firm-level cross-sectional regression to find that the negative and significant relation between MAX and expected stock return (known as the "MAX effect") is a non-January phenomenon observed predominantly on a sample of stocks with high idiosyncratic volatility. We find that the effect of investor sentiment on the MAX effect depends on arbitrage risk. Our findings suggest that arbitrageurs find it difficult to correct the mispricing of stocks with extreme positive return due to high idiosyncratic volatility, a support for the limits to arbitrage theory.

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DEDICATION

To the only wise God our Savior Jesus Christ, *be* glory and majesty, dominion and power, both now and ever. Amen. (Jude 1:25)

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CHAPTER ONE

INTRODUCTION

Bali, Cakici and Whitelaw (2011) document a new anomaly (the "MAX effect") that a negative and significant relation exist between daily maximum return (MAX) over the past one month and expected stock returns. They show that a MAX strategy that long high MAX stocks and short low MAX stocks produces an average value-weighted return of about -1.03% per month and a four factor alpha of -1.18% per month. They interpret their results to imply that investors are willing to pay more for stocks with extreme positive returns, and therefore, these stocks turn to generate lower returns in the future.[1] Other explanations for the MAX effect we could deduce from the literature are sentiment states (Fong and Toh (2014)) and seasonality (Doran, Jiang and Peterson (2012)).

In a recent study, Fong and Toh (2014) argue that investor sentiment captures investors' inclination to speculate as evident by the findings of Baker and Wurgler (2006) that show a high (low) sentiment to low (high) return relations for speculative stocks (i.e. small firms, young and highly volatile firms). They also argue that investor sentiment

[1] Bali, Cakici and Whitelaw (2011) pointed that their results are consistent with both the cumulative prospect theory of Barberis and Huang (2008) and the optimal beliefs framework of Brunnermeier, Gollier, and Parker (2007). Barberis and Huang (2008) argue that investors over-value stocks that have small probability of large returns due to errors in their probability weighting. Brunnermeier, Gollier, and Parker (2007) on the other hand argue that investors seek to maximize their current utility with an optimal chose to distort their beliefs about future probabilities.

captures investors' optimism or pessimism about stocks. This is consistent with Stambaugh et al. (2012) who find that many asset pricing anomalies are stronger following high sentiment states. Accordingly, Fong and Toh (2014) consider the role of investor sentiment in explaining the MAX effect. They document that the MAX effect is driven by high investor sentiment. They show that the high MAX to low returns phenomenon is observed (disappears) following a high (low) sentiment state.

Doran, Jiang and Peterson (2012) note some reasons why investors tend to gamble at the start of the year. First, investors have extra cash from bonuses paid out at the start of the year. Second, investors rebalance their portfolios motivated by tax-loss selling, receipt of end of year report on their investments, and the desire to buy stocks at the start of the New Year (see D'Mello, Ferris and Hwang (2003) and Starks, Young and Zheng (2006)). Lastly, investors engage in increased risk taking behavior especially if they experienced gains in the previous year (see Thaler and Johnson (1990)) or suffered a loss but are given an opportunity to break even (see Ackert et al. (2006), Coval and Shumway (2005), O'Connell and Teo (2007) and Liu et al. (2010)). Consequently, Doran, Jiang and Peterson (2012) argue that individual investors have a New Year's gambling preference that have a price impact on lottery-type stocks (i.e. low price, high IVOL and stocks with high idiosyncratic skewness). The authors' document that lottery-type stocks outperform (underperform) non lottery-type stocks in January (non-January) months.

A question that remains unanswered that could share some light in explaining the MAX effect is why investors hesitate to trade on the MAX effect. That rational investors would not exploit and therefore arbitrage away the MAX effect to make profit is puzzling. Barbaris and Thaler (2003) noted that because of cost (i.e., limits to arbitrage) mispricing persists as rational investors are unable to fully offset the choices of irrational investors. The most common cost or limit to arbitrage that is known to deter arbitrage activity is idiosyncratic risk (See DeLong, Sheifer, Summers, and Waldmann (1990), Pontiff (1996), Shleifer and Vishny (1997), Mitchell, Pulvino and Stafford (2002), and Wurgler and Zhuravskaya (2002)). Pontiff (2006) argues that idiosyncratic risk imposes significant holding cost for arbitrageurs and as a result, arbitrageurs tend to assign smaller portfolio weights to stocks with high idiosyncratic risk.

In this paper, we test the theory of limits to arbitrage by examining the cross-sectional relation between daily maximum return and expected return for stocks with low and high IVOL. Our testable hypothesis states that, if arbitrageurs find it more difficult to correct the mispricing of stocks due to high idiosyncratic risk, high IVOL stocks would be relatively more mispriced compared with low IVOL stocks. Thus, we expect the negative relation between extreme stock return and expected return, documented by Bali, Cakici and Whitelaw (2011), to persist only for high IVOL stocks and to disappear for low IVOL stocks.

Using a sample of U.S. stocks from 1965 to 2012, we find empirical evidence that is consistent with our hypothesis. We find that the negative relation between MAX and return in the following month is observed predominantly on the sample with high IVOL stocks. Our result is robust to the control of size, book-to-market, liquidity, short-term reversals, momentum, co-skewness and idiosyncratic skewness. We start our analysis by first investigating the presence of MAX effect in our sample. Specifically, we find results similar in spirit to the findings of Bali, Cakici and Whitelaw (2011); we find a negative and significant relation between the daily maximum return and stock return in the following month. Next, in the light of Doran, Jiang and Peterson (2012) findings that the New Year effect is driven by stocks with lottery features, we examine the significance of MAX in the cross-sectional pricing of stocks for January and non-January months. Consistent with Doran, Jiang and Peterson (2012), we find that the negative relation between daily maximum return and the return in the following month is purely a non-January phenomenon. We investigate whether this seasonality subsumes our results of limits to arbitrage on the MAX effect. Our evidence suggests that the high MAX to low realized return, even though a non-January phenomenon, persists because of high arbitrage cost.

Fong and Toh (2014) documented that the MAX effect is driven by high investor sentiment. We examine whether IVOL has incremental explanatory power beyond investor sentiment in explaining the MAX effect. We find that the effect of investor sentiment on the MAX effect depends on arbitrage risk; for low IVOL stocks, there is no MAX effect, not even when returns follow high investor sentiment months. For high IVOL stocks, the MAX effect disappears following low sentiment months and is strong following high sentiment months.

This study contributes to the literature by documenting the source of the MAX effect. We document that the high MAX to low return is a non-January occurrence, and is closely related to IVOL, a proxy for arbitrage risk. We also document that the effect of IVOL on the MAX effect is not subsumed by high investor sentiment but rather, the effect of investor sentiment on the MAX effect depends on arbitrage risk. Therefore, at least some of the usefulness of MAX in predicting returns is attributed to the significant impact of arbitrage costs.

The importance of our study is reinforced by previous studies that have considered the role of arbitrage cost as market-mispricing explanation for some market anomalies. Ali, Hwang and Trombley (2003), document that the book-to-market (B/M) effect is greater for stocks with higher arbitrage cost. Their study suggest that arbitrage costs deter arbitrageurs from exploring a trading strategy that long in high B/M stocks and short in low B/M stocks. Arena, Haggard and Yan (2008), document that momentum returns are higher among high IVOL stock, consistent with IVOL limiting arbitrageurs from exploring the momentum effect.

The remainder of the paper is organized as follows: Chapter Two describes the sample and key variables. In Chapter Three, we establish the effect of IVOL on the relation between MAX and the cross-section of future returns. Chapter Four concludes the study.

CHAPTER TWO

DATA AND VARIABLES

Our sample consists of all stocks traded on NYSE, AMEX, and NASDAQ from the period January 1965 to December 2012. We obtain monthly and daily returns and shares outstanding from the Center for Research in Security Prices (CRSP) database, book value data from the Standard and Poor's Compustat database, sentiment data from Jeff Wurgler's website and monthly risk-free rate and Fama-French factors return from Kenneth French's website[2]. We restrict the sample to firms with common code 10 and 11 and follow Brandt et al. (2010) to eliminate stocks with fewer than twelve daily observations in any given month to reduce noise associated with the calculation of IVOL. We use daily stock return to compute the maximum daily stock return (MAX) for each firm in each month:

$$MAX_{i,t} = \max(R_{i,1}, R_{i,2}, R_{i,3}, \ldots, R_{i,D_t}) \tag{1}$$

where $R_{i,d}$ $(d = 1,2,3, \ldots, D_t)$ is the return on stock i on day d, the number of trading days in month t.

[2] Data on the risk factors are obtained from Kenneth French website: http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

Consistent with the literature (e.g. Bali and Cakici (2008)), we compute monthly IVOL using daily return data. For each stock, we run contemporaneous daily

$$R_{i,d} - R_{f,d} = \alpha_i + \beta_i(R_{m,d} - R_{f,d}) + s_i SMB_d + \square_i HML_d + \varepsilon_{i,d} \qquad (2)$$

where $R_{i,d}$ is the return of stock i on day d; $R_{f,d}$ is the risk-free rate on day d; $(R_{m,d} - R_{f,d})$ is the market factor on day d; SMB_d is the Fama-French size factor on day d; HML_d is the Fama- French book-to-market factor on day d; and $\varepsilon_{i,d}$ is residual of stock i on day d. We obtained monthly IVOL of stock i on month t by multiplying the standard deviation of the residuals from equation (2) by the square root of the number of trading days in the month:

$$IVOL_{i,t} = \sqrt{\varepsilon_{i,d}} \times \sqrt{D_{i,t}} \qquad (3)$$

where $D_{i,t}$is the number of trading days for stock i in month t. Firm size (SIZE) is the natural logarithm of the stock's month-end market capitalization.

We estimate monthly beta using daily return data. We follow Scholes and Williams (1977) and Dimson (1979) in using the lag, current, and lead market portfolio in computing beta in order to mitigate the impact of non-synchronous trading:

$$R_{i,d} - R_{f,d} = \alpha_i + \beta_{1,i}(R_{m,d-1} - R_{f,d-1}) + \beta_{2,i}(R_{m,d} - R_{f,d}) + \beta_{3,i}(R_{m,d+1} - R_{f,d+1}) + \varepsilon_{i,d} \qquad (4)$$

where $R_{i,d}$ is the return on stock i on day d, $R_{f,d}$ is the risk-free rate on day d, and $R_{m,d}$ is the market return on day d measured by the CRSP daily value-weighted index. The estimated market beta of stock i in month t is given by $\hat{\beta}_i = \hat{\beta}_{1,i} + \hat{\beta}_{2,i} + \hat{\beta}_{3,i}$.

We follow Fama and French (1993) to compute firm's book-to-market ratio (B/M) in month t using the book value of equity for the fiscal year ending and market value of equity at the end of December of the prior calendar year. The book value of equity equals stockholders' equity, plus balance sheet deferred taxes and investment credit, minus the book value of preferred stock at the fiscal year ending. Consistent with the literature (e.g. Amihud (2002)), we defined stock illiquidity as the ratio of stock's absolute monthly return to its dollar trading volume:

$$ILLIQ_{i,t} = |R_{i,t}|/\$VOL_{i,t} \quad (5)$$

where $R_{i,t}$is the return of stock i in month t and $\$VOL_{i,t}$ is the respective monthly trading volume in dollars. Reversal variable (REV) is defined as the monthly stock return. We follow Jegadeesh and Timan (1993) in computing the momentum variable (MOM) for each stock in a given month defined as the buy and hold return over the past 12 months (i.e., the holding period return from month $t - 12$ to $t - 1$).

Finally, we derive both idiosyncratic skewness (ISKEW) and co-skewness (COSKEW) also known as systematic skewness, following Harvey and Siddique (2000) by estimating the following regression using daily return for each stock:

$$R_{i,d} - R_{f,d} = \alpha_i + \beta_i(R_{m,d} - R_{f,d}) + \gamma_i(R_{m,d} - R_{f,d})^2 + \varepsilon_{i,d} \quad (6)$$

where $R_{i,d}$, $R_{f,d}$, and $R_{m,d}$ are return on stock i on day d, risk-free rate on day d and CRSP value-weighted market index on day d, respectively. The ISKEW is the skewness of the residuals from equation (6) and the COSKEW is the estimated slope coefficient $\hat{\gamma}_i$ from equation(6). In section 3.1, we verify the existence of a negative and significant relation between the maximum daily return over the past one month and expected return.

CHAPTER THREE

EMPIRICAL RESULTS

MAX and the Cross-Section of Future Return

Table 1 presents results that relate maximum daily return and expected return. Every month, we sort NYSE/Amex/Nasdaq stocks into decile portfolios based on averages on the N (N=1, 2… 5) highest daily returns within the month (MAX(N)). We then present both the value- and equal-weighted average monthly returns of the decile portfolios for the following month. Portfolio 10 (high MAX(N)) is the portfolio of stocks with the highest average maximum daily return and portfolio one(low MAX(N)) is the portfolio with lowest average maximum daily return. The table also reports the value- and equal-weighted portfolio returns difference between high MAX(N) and low MAX(N) portfolios, along with their Newey and West (1987) adjusted *t*-statistics. Four-factor alphas for the difference between decile 10 and decile one portfolios and their Newey-West adjusted *t*-statistics are also reported. We do find indications of a negative MAX effect. High MAX and low MAX portfolio return differences and their four-factor alphas are negative and statistically significant for both value-weighted returns portfolios (panel A) and equal-weighted returns portfolios (panel B). Specifically, sorting on the single maximum daily return (N=1), the value-weighted return difference between high MAX and low MAX is -0.73% per month with a corresponding *t*-statistic of -2.31.

Table 1

Average Returns of Portfolios Formed on MAX

	N=1	N=2	N=3	N=4	N=5
Panel A: Value-Weighted Returns of Portfolios on MAX (N)					
Low MAX(N)	0.81	0.85	0.86	0.89	0.92
2	0.91	0.85	0.88	0.92	0.92
3	0.89	0.90	0.93	0.93	0.92
4	0.95	0.99	0.94	0.93	0.96
5	0.95	0.97	0.98	0.96	0.92
6	1.00	0.98	0.98	0.95	0.95
7	0.90	0.88	0.90	0.94	0.98
8	0.75	0.72	0.58	0.63	0.61
9	0.48	0.45	0.44	0.42	0.42
High MAX(N)	0.08	-0.07	-0.08	-0.10	-0.14
High - Low	-0.73 (-2.31)	-0.92 (-2.69)	-0.94 (-2.60)	-0.99 (-2.70)	-1.06 (-2.89)
Alpha	-1.03 (-3.81)	-1.24 (-4.14)	-1.21 (-3.68)	-1.27 (-3.79)	-1.33 (-3.91)
Panel B: Equal-Weighted Returns of Portfolios on MAX (N)					
Low MAX(N)	1.19	1.18	1.19	1.19	1.19
2	1.30	1.30	1.32	1.35	1.39
3	1.44	1.41	1.43	1.44	1.45
4	1.41	1.46	1.47	1.49	1.48
5	1.40	1.43	1.46	1.43	1.44
6	1.36	1.37	1.37	1.41	1.41
7	1.27	1.35	1.34	1.34	1.33
8	1.24	1.20	1.20	1.21	1.19
9	0.99	0.95	0.95	0.89	0.88
High MAX(N)	0.62	0.55	0.49	0.48	0.45
High - Low	-0.57 (-1.91)	-0.63 (-2.02)	-0.70 (-2.21)	-0.71 (-2.25)	-0.74 (-2.34)
Alpha	-0.75 (-2.70)	-0.84 (-2.86)	-0.93 (-3.15)	-0.96 (-3.24)	-1.10 (-3.41)

Note: This table reports the value- and equal-weighted average monthly returns of portfolios in month $t+1$. Decile portfolios are formed based on the average of the N highest daily returns (MAX(N)) each month t. Low (High) MAX(N) is the portfolios of stocks with the lowest (highest) MAX(N) in month t. Stocks from NYSE, AMEX, and NASDAQ with at least 12 daily observations in each month are included in the sample from January 1965 to December 2012. Alpha reports 4-factor (market beta, size, book-to-market, and momentum) alpha. Newey-West (1987) adjusted t-statistics are reported in parentheses.

The corresponding difference in four-factor alphas between the high and low MAX portfolios is -1.03 with a Newey-West t-statistic of -3.81. Decile one- eight have about the same average return, but decile nine and 10 show a steep drop in average returns. Our results for univariate sort on MAX (1) do reveal a strong negative relation between MAX and expected stock return. Sorting based on average returns over multiple days MAX(N) N=2, …, 5, eliminates the arbitrariness associated with conditioning on the single day MAX(1). However, the results are similar to results for sort on MAX(1); return and alpha differences between high and low MAX portfolios are both negative and statistically significant.

Our results are similar to the findings of Bali, Cakici and Whitelaw (2011)[3] as we find a negative and significant relation between the maximum (both single- and multi-day) return and expected stock return. In other words, stocks with a high positive return during the month tend to generate lower return in the following month. We question why arbitrageurs are unable to offset the MAX effect by simply going long on low MAX stocks and going short on high MAX stocks. We investigate this issue by examining the limits to arbitrage in the next section.

MAX Effect and Idiosyncratic Volatility

To investigate whether arbitrageurs are unable to explore the MAX effect due to arbitrage cost, we test whether MAX effect is related to idiosyncratic volatility. We use a method similar to that of Lee and Swaminathan (2000) and Arena, Haggard, and Yan (2008) and group stocks into three portfolios based on IVOL (Low IVOL, Medium IVOL and High IVOL). For each IVOL portfolio, we form decile portfolios based on the average of N(N=1, …, 5) highest daily returns (MAX(N)) for each month t. This result in sorts on IVOL and MAX(N). Results on value- and equal-weighted average monthly returns of each portfolio in month $t+1$ are reported in Table 2.

[3] Our findings do not exactly replicate the findings of Bali, Cakici and Whitelaw (2011) because of sample period differences. We also follow Brandt et al. (2010) to eliminate stocks with less than 12 daily observations in any given month to reduce the noise related to the computation of idiosyncratic volatility.

Table 2

Average Returns of Portfolios Formed on IVOL and MAX

	N=1			N=5		
Panel A: Value-Weighted Returns of Portfolios on MAX						
	Low IVOL	2	High IVOL	Low IVOL	2	High IVOL
Low MAX(N)	0.74	0.96	0.59	0.86	1.16	0.95
2	0.84	1.03	0.42	0.89	1.21	0.72
3	0.86	1.21	0.46	0.91	1.19	0.67
4	0.94	1.13	0.54	1.04	1.10	0.53
5	0.90	0.98	0.57	0.96	1.01	0.38
6	1.02	0.98	0.22	0.93	1.06	0.54
7	0.86	1.11	0.31	0.98	1.06	0.15
8	0.84	0.98	0.22	0.90	0.96	0.27
9	0.84	1.14	0.04	0.89	1.05	-0.10
High MAX(N)	0.90	0.94	-0.31	0.68	0.84	-1.15
High - Low	0.16 (1.01)	-0.02 (-0.12)	-0.89 (-3.24)	-0.18 (-1.19)	-0.32 (-1.46)	-2.09 (-6.37)
Alpha	0.21 (1.20)	-0.03 (-0.15)	-0.94 (-3.00)	-0.18 (-1.06)	-0.30 (-1.49)	-2.18 (-5.38)
Panel B: Equal-Weighted Returns of Portfolios on MAX						
Low MAX(N)	1.03	1.68	2.31	1.04	1.69	2.83
2	1.06	1.61	1.46	0.98	1.76	1.74
3	1.24	1.50	1.30	1.23	1.56	1.40
4	1.25	1.47	1.26	1.35	1.46	1.13
5	1.30	1.32	1.08	1.34	1.38	1.01
6	1.27	1.35	0.96	1.31	1.36	0.86
7	1.26	1.25	0.87	1.30	1.31	0.80
8	1.29	1.22	0.60	1.27	1.15	0.60
9	1.19	1.15	0.67	1.20	1.11	0.48
High MAX(N)	1.14	1.10	0.57	0.94	0.86	0.27
High - Low	0.11 (1.39)	-0.58 (-5.78)	-1.74 (-7.10)	-0.09 (-0.66)	-0.83 (-5.71)	-2.56 (8.93)
Alpha	0.04 (0.41)	-0.55 (-4.57)	-1.76 (-6.70)	-0.23 (-1.89)	-0.89 (-5.63)	-2.76 (-8.81)

Note: This table reports the value- and equal-weighted average monthly returns of portfolios in month $t + 1$. Stocks from NYSE, AMEX, and NASDAQ with at least 12 daily observations in each month t are grouped into three portfolios based on idiosyncratic volatility from January 1965 to December 2012. Then, decile portfolios are formed based on the average of the N highest daily returns (MAX(N)) each month t using three separate samples of stocks based on idiosyncratic volatility. Low (High) MAX(N) is the portfolios of stocks with the lowest (highest) MAX(N) in month t. Idiosyncratic volatilities are the square root of the number of trading days times the standard deviation of residuals from the regression of excess daily stock returns on the contemporaneous daily Fama-French factors in the month. Alpha reports 4-factor (market beta, size, book-to-market, and momentum) alpha. Newey-West (1987) adjusted t-statistics are reported in parentheses.

Return differences together with four-factor alpha differences between decile and decile one and their respective Newey-West adjusted *t*-statistics are also reported[4]. Table 2 Panel A (Panel B) reports the results of value-weighted (equal-weighted) returns of portfolios on MAX. The MAX effect increases across IVOL portfolios. For low IVOL portfolio, we do not find any significant indication of a negative MAX effect; return and alpha differences are statistically not different from zero for both value-weighted and equal-weighted portfolios. For high IVOL portfolio, we find a negative relation between daily MAX and return in the following month. Specifically, for high IVOL when portfolio formation is based on MAX(1), the value-weighted return difference (alpha difference) is -0.89% (-0.94%) and are statistically significant with a *t*-statistic of -3.24 (-3.00) respectively. A closer look suggests that the persistence of the MAX effect is primarily driven by the underperformance of high IVOL-high MAX stocks. We find that low IVOL, high MAX stocks generate increased future positive return, while high IVOL, high MAX stocks generates a complete return reversal. For example, for sort on MAX(1), the low IVOL, high MAX stocks generate a value-weighted return of 0.90%, while high IVOL, high MAX stocks produce a value weighted return of -0.31%.

Controlling for Size, Book-to-Market, Momentum, Reversal, Illiquidity, Coskewness and Idiosyncratic Skewness

First, we develop summary statistics on various characteristics for stocks in decile portfolio formed based on maximum daily returns in month *t*. Table 3 presents time-series averages of cross-sectional median value of these characteristics.

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[4] We only report results for portfolios that are form on MAX(1) and MAX(5). Results are similar when portfolios are formed on MAX(2), MAX(3), and MAX(4).

Table 3

Summary Statistic of Portfolios Formed on MAX

	MAX	SIZE	PRICE	BETA	B/M	ILLIQ	REV	MOM	COSKEW	ISKEW	IVOL
Low MAX	1.10	11.14	18.43	0.18	0.85	0.26	-1.78	4.20	-0.02	-0.65	4.04
2	2.41	12.19	23.22	0.46	0.78	0.16	-1.11	9.92	-0.04	-0.11	6.08
3	3.23	12.01	20.90	0.62	0.74	0.15	-0.65	9.73	-0.04	0.00	7.69
4	4.04	11.77	18.59	0.73	0.72	0.18	-0.28	9.29	-0.05	0.07	9.19
5	4.92	11.50	16.27	0.83	0.71	0.24	0.17	8.88	-0.06	0.15	10.76
6	5.96	11.24	13.92	0.93	0.71	0.32	0.56	7.62	-0.06	0.23	12.53
7	7.27	10.95	11.41	1.02	0.71	0.45	1.13	5.73	-0.08	0.32	14.64
8	9.09	10.62	9.02	1.07	0.72	0.71	2.09	2.84	-0.12	0.43	17.39
9	12.13	10.20	6.62	1.12	0.74	1.35	3.61	-1.60	-0.17	0.60	21.74
High MAX	20.52	9.51	3.81	1.15	0.76	4.08	8.88	-11.36	-0.38	1.04	34.15

Notes. This table reports time-series averages of cross-sectional median values each month of portfolios formed based on the maximum daily returns each month t. MAX is the maximum daily return of a stock in month t. Low (High) MAX is the portfolios of stocks with the lowest (highest) MAX in month t. Stocks from NYSE, AMEX, and NASDAQ with at least 12 daily observations in each month are included in the sample from January 1965 to December 2012. SIZE is log of market capitalization. BETA is the market beta. B/M is the book-to-market ratio. ILLIQ is illiquidity measure scaled by 100,000. REV is monthly return in the current month t when decile portfolios are formed. MOM is return from t -12 to t -1. COSKEW is a measure for coskewness. ISKEW is idiosyncratic skewness. IVOL is idiosyncratic volatility. The detailed explanations are provided in the main text.

We report values of maximum daily return, size, price, market beta, B/M, ILLIQ, REV, MOM, COSKEW, ISKEW and IVOL. Most variables show similar pattern across decile portfolios as in Table V in Bali, Cakici, and Whitelaw (2011).[5] As we move from low MAX to high MAX decile, the averages across months of the median MAX increases from 1.10% to 20.52%. Bali, Cakici, and Whitelaw (2011) show an increase from 1.62% to 17.77%. Both results clearly suggest that the distribution of MAX is right-skewed. Also, consistent with Bali, Cakici and Whitelaw, our size distribution suggests that high MAX portfolio is dominated by smaller stocks.[6] As we move from low MAX to high MAX decile, prices decline from a median price of $18.43 for decile one to $3.81 for decile 10. Bali, Cakici and Whitelaw (2011) noted that because the MAX effect is seen on both value-weighted as well as equal-weighted portfolios nullify concerns that MAX effect could be an artifact of measurement issues associated with microstructure occurrences with some of the small, low-priced stocks in the high MAX portfolio.[7] The distribution of beta shows that as MAX increases, beta increases. This implies that high MAX stocks are more exposed to market risk than low MAX stocks. Any beta effect should be controlled by the difference in the four-factor alphas. Median B/M ratios are fairly the same for an estimated half of the decile portfolios. Low-MAX stocks have

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[5] We used median statistics to make our results comparable with those of Bali, Cakici, and Whitelaw (2011). More so, the median is the preferred measure of central location, whenever a data set has extreme values.

[6] Bali, Cakici and Whitelaw (2011) noted that the concentration of small stocks in high MAX decile may partially explain why alpha difference exceeds the difference in raw return. They argue that small stocks should earn a return premium, not the return discount observed in the data.

[7] Additionally, Bali, Cakici and Whitelaw (2011) find that the MAX effect is robust to different sample selection procedures: excluding stocks with price below $5/share, excluding all Amex and Nasdaq stocks, and using NYSE decile breakpoint to exclude stocks with market capitalization within the smallest NYSE size quintile.

slightly higher B/M relative to high-MAX stocks. On the other hand, liquidity measure show large variation between high and low MAX decile portfolios, with high MAX stocks exhibiting high illiquidity. This is consistent with Bali, Cakici and Whitelaw (2011), who show that illiquidity increases drastically for high MAX stock. This is also consistent with the fact that high MAX decile contains smaller stocks. Turning to return reversals (REV), we find a monotonic increase in median monthly return as MAX increases. This is as expected given that we formed portfolios based on MAX and we can expect a high median returns in the same month. When we look more carefully, we find that the median monthly returns (REV) are smaller compared to median MAX. This suggests that stocks with extreme daily return turn to exhibit lower returns on other days albeit still exhibiting a higher frequency of extreme returns. The decline of future return as MAX increases is even more imminent over an intermediate horizon. There is a decrease in momentum return as MAX increases, with high MAX portfolio generating a negative momentum return. The last three columns in Table 3 reports the COSKEW, ISKEW and IVOL of the MAX sorted portfolios. MAX and coskewness are negatively correlated whereas MAX and idiosyncratic skewness, and MAX and idiosyncratic volatility are positively correlated in the cross-section. In summary, we find that high MAX portfolio is associated with high median return, smaller stocks, low priced stocks, high betas, slightly lower B/M, higher illiquidity, high return on the month of portfolio formation, lower and even negative intermediate momentum return, high absolute coskewness, high idiosyncratic skewness and high idiosyncratic volatility. Most variables show similar pattern across decile portfolios as Table V in Bali, Cakici, and Whitelaw (2001).

Bali, Cakici and Whitelaw (2011) show that the negative MAX effect is not an artifact of firm characteristics, by controlling size, B/M, ILLIQ, REV, MOM, COSKEW and ISKEW. Next we investigate if idiosyncratic volatility has incremental explanatory power on the MAX effect beyond these variables. We start by grouping stocks into tercile portfolios on IVOL and then, within each tercile portfolios, we formed decile portfolios on the control variables. Within each control decile, we formed another decile portfolio on daily maximum returns (MAX). Table 4 reports average returns across the 10 control decile portfolios within the lowest tercile portfolio on IVOL (V1) and the highest tercile portfolio on IVOL (V3). Panel A of Table 4 reports the value-weighted average monthly returns in month *t*+1 while panel B of Table 4 reports the equal-weighted average monthly returns. The MAX effect is calculated as the difference in average monthly returns between the high-MAX and low-MAX portfolios, and the difference in four-factor alphas on the high-MAX and low-MAX portfolios. The differences are reported together with their respective Newey-West (1987) adjusted *t*-statistics.[8]

In Table 3, we document that high MAX stocks are associated with smaller stocks. Therefore it is important to examine whether the effect of idiosyncratic volatility on the MAX effect is subsumed by size. Column one in Panel A of Table 4 presents the value-weighted return for the variations in MAX after controlling for size within IVOL tercile one and three portfolio. The negative relation between MAX and return in the following month is concentrated among stocks with High IVOL. For low IVOL portfolio, we find no indication of a negative MAX effect.

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[8] For brevity, we do not report results on the second tercile idiosyncratic volatility portfolio.

Table 4

Average Returns of Portfolios Formed on MAX After Controlling for Size, B/M, MOM, REV, ILLIQ, COSKEW, and ISKEW Across Portfolios on IVOL

Panel A: Value-weighted Returns														
	SIZE		B/M		ILLIQ		REV		MOM		COSKEW		ISKEW	
	V1	V3	V1	V3	V1	V3	V1	V3	V1	V3	V1	V3	V1	V3
Low MAX	0.77	2.14	0.75	1.14	0.91	1.62	0.66	1.14	0.77	1.17	0.81	0.96	0.87	1.44
2	1.04	1.68	0.95	0.88	1.05	1.21	0.85	1.09	0.99	0.58	1.00	0.66	1.12	1.09
3	1.16	1.52	0.90	0.95	1.08	0.86	1.04	0.93	1.00	0.41	0.97	0.56	1.18	0.94
4	1.21	1.30	0.98	0.70	1.07	0.78	1.13	1.05	0.95	0.44	1.00	0.53	1.16	0.92
5	1.21	1.22	1.01	0.78	1.10	0.75	1.19	0.84	1.08	0.31	0.92	0.39	1.20	0.74
6	1.21	0.94	1.09	0.44	1.13	0.54	1.19	0.78	0.97	0.08	0.96	0.47	1.19	0.72
7	1.21	0.79	0.90	0.60	1.00	0.40	1.25	0.78	0.98	0.09	0.97	0.15	1.23	0.64
8	1.22	0.48	0.96	0.20	1.00	0.17	1.25	0.56	0.99	-0.11	0.88	0.13	1.18	0.32
9	1.15	0.19	0.92	-0.01	0.87	-0.20	1.27	0.33	0.84	-0.35	0.88	-0.11	1.13	0.21
High MAX	1.03	-0.56	1.01	-0.14	0.85	-0.65	1.27	0.05	0.82	-0.88	0.91	-0.41	1.04	0.23
High - Low	0.25 (2.84)	-2.70 (-15.39)	0.27 (2.21)	-1.28 (-5.73)	-0.06 (-0.71)	-2.27 (-11.99)	0.60 (6.30)	-1.09 (-6.60)	0.05 (0.42)	-2.05 (-9.98)	0.10 (0.93)	-1.38 (-6.91)	0.17 (1.78)	-1.21 (-6.15)
Alpha	0.12 (1.46)	-2.75 (-12.43)	0.21 (1.73)	-1.29 (-5.84)	-0.18 (2.25)	-2.24 (-10.36)	0.47 (5.59)	-1.09 (-5.83)	0.02 (0.19)	-2.23 (-10.16)	0.07 (0.6)	-1.36 (-5.68)	0.00 (0.03)	-1.27 (-6.60)

Panel B: Equal-weighted Returns														
	SIZE		B/M		ILLIQ		REV		MOM		COSKEW		ISKEW	
	V1	V3	V1	V3	V1	V3	V1	V3	V1	V3	V1	V3	V1	V3
Low MAX	0.95	2.38	0.88	2.35	1.07	2.09	0.79	1.27	0.84	2.48	0.74	2.35	1.02	1.68
2	1.15	1.84	1.12	1.69	1.21	1.68	0.95	1.30	1.13	1.67	1.15	1.54	1.22	1.32
3	1.23	1.71	1.15	1.45	1.27	1.42	1.14	1.14	1.28	1.28	1.25	1.19	1.27	1.15
4	1.30	1.52	1.15	1.36	1.25	1.45	1.22	1.25	1.23	1.39	1.29	1.26	1.24	1.10
5	1.27	1.39	1.23	1.23	1.29	1.29	1.27	1.07	1.31	1.13	1.23	1.15	1.30	0.94
6	1.29	1.17	1.25	1.04	1.32	1.11	1.27	0.98	1.29	1.01	1.27	0.99	1.29	0.95
7	1.26	1.07	1.26	1.03	1.25	1.00	1.34	1.06	1.25	1.05	1.26	0.82	1.30	0.85
8	1.28	0.80	1.17	0.72	1.25	0.84	1.33	0.85	1.23	0.76	1.21	0.77	1.26	0.60
9	1.19	0.50	1.12	0.82	1.13	0.45	1.34	0.65	1.17	0.63	1.22	0.60	1.22	0.57
High MAX	1.10	-0.23	1.10	0.75	1.04	0.07	1.35	0.55	1.10	0.20	1.16	0.51	1.14	0.63
High - Low	0.15	-2.60	0.22	-1.60	-0.03	-2.01	0.56	-0.72	0.26	-2.28	0.42	-1.84	0.12	-1.05
	(1.72)	(-12.46)	(2.01)	(-6.35)	(-0.31)	(-8.74)	(5.83)	(-3.93)	(2.79)	(-9.80)	(4.84)	(-8.06)	(1.25)	(-4.51)
Alpha	0.03	-2.63	0.15	-1.60	-0.18	-2.03	0.44	-0.77	0.16	-2.46	0.31	-1.90	-0.01	-1.14
	(0.34)	(-11.19)	(1.46)	(-6.16)	(-2.17)	(-8.87)	(4.81)	(-3.79)	(1.79)	(-9.13)	(2.94)	(-7.73)	(-0.16)	(-4.53)

Note. This table reports the value- and equal-weighted average monthly returns in month t +1 of portfolios on the maximum daily returns after controlling for firm characteristics each month t using separate tercile portfolios on IVOL. MAX is the maximum daily return of a stock in month t. Low (High) MAX is the portfolios of stocks with the lowest (highest) MAX in month t. Stocks from NYSE, AMEX, and NASDAQ with at least 12 daily observations in each month are included in the sample from January 1965 to December 2012. Each month t, stocks are grouped into tercile portfolios on IVOL and then, using separate tercile portfolios, decile portfolios are formed on the control variables, then within each decile, another decile portfolios are formed on daily maximum returns. V1 (V3) is the lowest (highest) tercile portfolio on IVOL. This table reports average returns across the 10 control decile portfolios. SIZE is log of market capitalization. BETA is the market beta. B/M is the book-to-market ratio. ILLIQ is illiquidity measure scaled by 100,000. REV is monthly return in the current month t when decile portfolios are formed. MOM is return from t -12 to t -1. COSKEW is a measure for coskewness. ISKEW is idiosyncratic skewness. IVOL is idiosyncratic volatility. The detailed explanations are provided in the main text.

Specifically, for a sample of High IVOL stocks, the value-weighted return differences and the four-factor alpha differences are -2.70% and -2.75% respectively. They are also statistically significant with *t*-statistics of -15.39 and -12.43 respectively. For the sample of low IVOL stocks, return differences are rather positive at 0.25% per month, and even significant with a *t*-statistics of 2.84. Alpha differences are also positive but not statistically significance.

To show that our results are not driven by B/M, we check the variability of return on MAX after controlling for B/M within IVOL tercile portfolios. The results suggest that the high MAX to low realized return phenomenon is concentrated among the high IVOL stocks. The value-weighted (High–Low) return difference and four-factor alpha difference for high IVOL stocks are negative and statistically significant. The corresponding value weighted (High–Low) return difference and four-factor alpha difference for low IVOL stocks are rather positive. Therefore, B/M does not eliminate the positive relation between IVOL and the MAX effect.

The column three in Panel A of Table 4 presents results that investigate the relation between IVOL and the MAX effect controlling for illiquidity by forming portfolios on IVOL, illiquidity and MAX. Again, the results confirm that the negative relation between daily MAX and realized return is concentrated among the high IVOL stocks. Specifically, for a sample of High IVOL stocks, the value-weighted (High–Low) return difference and the four-factor alpha difference are -2.27% and -2.24% per month, and are statistically significant with *t*-statistics of -11.99 and -10.36 respectively. For the sample of Low IVOL stocks, (High–Low) return difference is statistically indifferent from zero. The (High–Low) four-factor alpha difference is negative and statistically significant but as documented in Table 6, for low IVOL stocks, the relations between daily MAX and realized return becomes insignificant with the inclusion of other control variables.

In Table 3, we document that high MAX is associated with high return (REV) on the month of portfolio formation. To investigate if our results of limits to arbitrage on the MAX effect are driven by short-term reversals, we form portfolios on IVOL, return on the month of portfolio formation and then on MAX. We find MAX effect on high IVOL stocks and no indication of MAX effect on low IVOL stocks. For high IVOL stocks, both the value-weighted (High–Low) return difference and the four-factor alpha difference are both -1.09% per month, and are statistically significant with *t*-statistics of -6.60 and -5.83 respectively. For the corresponding sample of Low IVOL stocks, value-weighted (High–Low) return difference and four-factor alpha difference are positive at 0.60% and 0.47% per month, and are even significant with a *t*-statistics of 6.30 and 5.59 respectively. Therefore our results are robust to the control of short-term reversal.

We also document that high MAX is associated with lower and even negative intermediate momentum return (See Table 3). Accordingly, we examine that our results are not driven by momentum. Column five in Panel A of Table 4 present results of average returns for portfolios formed on IVOL, intermediate momentum, and MAX. We find that the MAX effect is concentrated on high IVOL stocks even after controlling for intermediate momentum.

High MAX is associated with high absolute COSKEW (see Table 3). Therefore it is important to investigate whether the effect of IVOL on the MAX phenomenon is subsumed by COSKEW. We check the variability of return on MAX portfolios after controlling for IVOL and COSKEW. Results in column 6, Panel A of Table 5 suggests that the MAX effect is concentrated among the high IVOL stocks. Specifically, for the sample of High IVOL stocks, the value-weighted (High–Low) return difference and the four-factor alpha difference are -1.38% and -1.36%, and are statistically significant with *t*-statistics of -6.91 and -5.68 respectively. For the sample of Low IVOL stocks, the value-weighted (High–Low) return difference and alpha difference are rather positive at 0.10% and 0.07% per month, and are statistically not different from zero.

Lastly, it is also important to show that our results are not driven by ISKEW especially as we document that high MAX is associated with high ISKEW (see Table 3). Results presented in column seven of Table 4 show that IVOL have incremental explanatory power on the MAX effect beyond ISKEW. The results suggest that the high MAX to low realized return occurrence is concentrated among the high IVOL stocks. Specifically, for a sample of high IVOL stocks, the value-weighted (High–Low) return difference and the four-factor alpha difference are -1.21% and -1.27%, and are statistically significant with *t*-statistics of -6.15 and -6.60 respectively. For the sample of Low IVOL stocks, the value-weighted (High–Low) return difference and alpha difference are rather positive and statistically not different from zero.

Table 4 Panel B provides results of equal-weighted return that are similar to those of value-weighted returns presented in panel A. IVOL has incremental explanatory power on the MAX effect beyond size, B/M, ILLIQ, REV, MOM, COSKEW and ISKEW. In summary, Table 4 show that even after controlling for firm characteristics, the negative relation between daily MAX and the return in the following month is concentrated for stocks with high IVOL, a proxy for limits to arbitrage.

Considering the January Effect

Evidence presented by Doran, Jiang and Peterson (2012) suggest that the New Year effect is driven by stocks with lottery features. Therefore we consider the implication of such seasonality on our results. We start by investigating the significance of MAX in the cross-sectional pricing of stocks for January and non-January months. Table 5 Panel A reports average value- and equal-weighted monthly returns of decile portfolios formed on MAX for January and non-January months. For non-January months, we find indications of the high MAX to low realized return phenomenon. Specifically, the value-weighted (equal-weighted) return difference between high MAX and low MAX is -0.73% (-0.60%) per month and is statistically significant with a corresponding *t*-statistic of -2.25 (-2.07). For value-weighted (equal-weighted) return, the difference in four-factor alphas between the high and low MAX portfolios is -0.97% (-0.70%) per month and is statistically significant with a Newey-West *t*-statistic of -3.57 (-2.74). For January months, we find weak indication of a negative relation between MAX and realized return. The value-weighted (equal-weighted) return differences and four-factor differences between high MAX and low MAX portfolio are statistically not different from zero. In summary, results from panel A of Table 5 suggest that the negative relation between daily MAX and the return in the following month is purely a non-January phenomenon. This is consistent with Doran, Jiang and Peterson (2012) findings that stocks with lottery-like features outperform in January and underperform in other months.

Table 5

Average Returns of Portfolios Formed on IVOL and MAX: January vs. Non-January

Panel A: Entire Sample				
	January		Non-January	
	VW	EW	VW	EW
Low MAX	0.48	1.77	0.84	1.13
2	0.42	1.30	0.95	1.30
3	0.57	1.43	0.92	1.44
4	0.45	1.35	1.00	1.42
5	0.52	1.44	0.99	1.40
6	0.61	1.37	1.03	1.36
7	0.58	1.25	0.93	1.27
8	0.12	1.25	0.81	1.23
9	0.12	1.27	0.52	0.97
High MAX	-0.28	1.51	0.11	0.54
High - Low	-0.76 (-0.57)	-0.26 (-0.20)	-0.73 (-2.25)	-0.60 (-2.07)
Alpha	-1.27 (-1.53)	-1.02 (-1.32)	-0.97 (-3.57)	-0.70 (-2.74)

Panel B: Lowest and Highest Tercile Portfolios on IVOL								
	January				Non-January			
	V1		V3		V1		V3	
	VW	EW	VW	EW	VW	EW	VW	EW
Low MAX	0.80	2.08	0.13	1.87	0.74	0.93	0.63	2.35
2	0.39	0.94	-0.09	1.27	0.88	1.07	0.47	1.48
3	0.50	1.38	0.07	1.83	0.89	1.22	0.50	1.25
4	0.56	1.15	-0.89	0.74	0.97	1.26	0.67	1.31
5	0.45	1.44	0.94	1.26	0.94	1.28	0.54	1.07
6	0.41	1.24	-0.95	0.88	1.07	1.28	0.32	0.96
7	0.27	1.33	0.21	1.53	0.91	1.25	0.32	0.81
8	0.77	1.42	0.51	1.36	0.85	1.28	0.19	0.53
9	0.54	1.41	-0.89	1.36	0.87	1.17	0.12	0.61
High MAX	0.80	1.51	-0.14	1.78	0.91	1.11	-0.32	0.46
High - Low	-0.01 (-0.01)	-0.56 (-1.42)	-0.27 (-0.25)	-0.09 (-0.10)	0.17 (1.07)	0.22 (1.92)	-0.95 (-3.33)	-1.89 (-7.56)
Alpha	0.51 (0.95)	-0.41 (-1.47)	-1.49 (-1.53)	-0.96 (-1.31)	0.17 (0.94)	0.08 (0.74)	-0.88 (-2.65)	-1.81 (-6.63)

Note: This table reports the value and equal weighted average monthly returns of portfolios in month $t + 1$. Stocks from NYSE, AMEX, and NASDAQ with at least 12 daily observations in each month t are grouped into three portfolios based on idiosyncratic volatility from January 1965 to December 2012. Then, decile portfolios are formed based on MAX (maximum daily return) each month t using three separate samples of stocks based on idiosyncratic volatility. V1 (V3) is the lowest (highest) tercile portfolio on IVOL. Low (High) MAX is the portfolios of stocks with the lowest (highest) MAX in month t. Idiosyncratic volatilities are the square root of the number of trading days times the standard deviation of residuals from the regression of excess daily stock returns on the contemporaneous daily Fama-French factors in the month. Alpha reports 4-factor (market beta, size, book-to-market, and momentum) alpha. Newey-West (1987) adjusted t-statistics are reported in parentheses.

Next, we examine if this seasonality subsume our results on limits to arbitrage. We formed tercile portfolio for each month based on IVOL. Then for each month, decile portfolios are formed based on MAX within the three separate samples of IVOL stocks. In Panel B of Table 5, we report the average value- and equal-weighted monthly returns of decile portfolios formed on MAX for January and non-January months.[9] For January month, return differences and four-factor differences between high MAX and low MAX are statistically not different from zero irrespective of weighting scheme and after controlling for IVOL. For non-January months, we find that the negative relation between MAX and return in the following month is observed predominantly on the sample with high IVOL stocks. For high IVOL portfolio, the value-weighted (equal-weighted) return difference between high MAX and low MAX is -0.95% (-1.89%) per month and is strongly statistically significant with corresponding *t*-statistics of -3.33 (-7.56). The corresponding four-factor alpha difference is -0.88% (-1.81%) per month, is also significant with a Newey-West *t*-statistic of -2.65 (-6.63). For low IVOL portfolio, we do not find any indication of a negative MAX effect. Both the value- and equal-weighted return differences and their corresponding four-factor alpha differences are statistically not different from zero. Overall, Table 5 suggests that the high MAX to low return is a non-January phenomenon that persists because of high arbitrage cost.

Firm-Level Cross-Sectional Regression

In the previous section, we used portfolio level analyses to test the implication of limits to arbitrage on the significance of MAX as a determinant of the cross-section of expected returns. Even though aggregating may give more power in a statistical test, we

[9] For brevity, we do not report results on the second tercile idiosyncratic volatility portfolio.

lose firm specific information. Consequently, we now use Fama and MacBeth (1973) regression to investigate the role of limits to arbitrage on the MAX effect. Fama-MacBeth regression has an advantage of incorporating cross-sectional information that might have been lost in portfolio analysis above. With Fama-MacBeth regression, we can control for the effects of multiple variates shown to relate to stock returns, such as size, Beta, B/M, ILLIQ, REV, MOM, COSKEW and ISKEW. Accordingly, we estimate the following equation:

$$R_{i,t+1} = a_{0,t} + a_{1,t}MAX_{i,t} + a_{2,t}SIZE_{i,t} + a_{3,t}BETA_{i,t} + a_{4,t}B/M_{i,t} + a_{5,t}ILLIQ_{i,t} + a_{6,t}REV_{i,t} + a_{7,t}MOM_{i,t} + a_{8,t}COSKEW_{i,t} + a_{9,t}ISKEW_{i,t} + \varepsilon_{i,t+1} \quad (7)$$

where $R_{i,t+1}$is the monthly return of stock i in month $t + 1$, $MAX_{i,t}$ the main predictive variable, is the daily maximum return of stock i in month t. The control variables are size, Beta, Book to Market (B/M), illiquidity (ILLIQ), short-term return reversal (REV), intermediate momentum (MOM), co-skewness (COSKEW) and idiosyncratic skewness (ISKEW).[10] The results are reported in Table 6. We report time series averages of the coefficient estimates from monthly cross-sectional regressions together with their Newey-West adjusted t-statistics given in parentheses. The regression (1) of Table 6 reports univariate regression results on the entire sample of stocks. Consistent with prior findings by Bali, Cakici and Whitelaw (2011), we find a negative and significant relation between MAX and the cross-section of expected stock returns. Specifically, the average slope from the monthly regressions of realized returns on MAX is -0.035 with a t-statistic

[10] We do not control for total skewness because total skewness is highly related with idiosyncratic skewness (See Table XIII in Bali, Cakici, and Whitelaw (2011)).

of -3.43. Regression (2) of Table 6 reports results for the full specification with MAX and eight control variables. The high MAX to low realized return is robust to the control of size, beta, B/M, liquidity, return reversal, momentum, co-skewness and idiosyncratic skewness. The average slope of MAX is -0.028 and is statistically significant with a Newey-West t-statistic of -3.03.

Table 6

Firm-Level Fama-MacBeth Cross-Sectional Regression

	Entire Sample		V1		V3	
	(1)	(2)	(3)	(4)	(5)	(6)
MAX	-0.035 (-3.43)	-0.028 (-3.03)	0.036 (1.86)	0.093 (3.58)	-0.044 (-6.77)	-0.024 (-2.82)
SIZE		-0.161 (-3.63)		-0.080 (-2.33)		-0.533 (-7.38)
BETA		0.014 (0.59)		0.136 (4.17)		0.007 (0.35)
B/M		0.134 (2.57)		0.089 (1.44)		0.129 (2.11)
ILLIQ		0.023 (4.10)		-0.001 (-0.01)		0.036 (3.76)
REV		-0.065 (-11.44)		-0.072 (-9.09)		-0.067 (-10.74)
MOM		0.692 (3.93)		0.711 (4.59)		0.584 (2.38)
COSKEW		0.153 (2.14)		0.088 (0.80)		0.142 (2.17)
ISKEW		0.129 (4.90)		0.064 (2.88)		0.116 (2.94)

Note. This table reports the results of Fama-MacBeth cross-sectional regression of individual firms' returns in month $t + 1$ on control variables in month t. Stocks from NYSE, AMEX, and NASDAQ with at least 12 daily observations in each month t are included in the regression from January 1965 to December 2012. Each month t, stocks are grouped into tercile portfolios on IVOL. V1 (V3) is the lowest (highest) tercile portfolio on IVOL. MAX is maximum daily return in month t. BETA is the market beta. B/M is the book-to-market ratio. ILLIQ is illiquidity measure scaled by 100,000. REV is monthly return in the current month t when decile portfolios are formed. MOM is return from t -12 to t -1. COSKEW is a measure for coskewness. ISKEW is idiosyncratic skewness. IVOL is idiosyncratic volatility. The detailed explanations are provided in the main text. Newey-West (1987) adjusted t-statistics are reported in parentheses.

Our control variables generate coefficients that are largely consistent with prior findings. Consistent with Fama and French (1993), the size effect is negative and significant, while value effect (B/M) is positive and significant. Also, illiquidity is positive and significant (Amihud (2002)) and stock returns exhibit short term reversal (Jegadeesh (1990) and Huang, Liu, Rhee and Zhang (2010)) and intermediate momentum (Jegadeesh and Titman (1993, 2001)). co-skewness and idiosyncratic skewness are also priced in the cross section of returns. Although the average beta coefficient is positive, it is statistically insignificant, which contradicts the predictions of CAPM.

Turning to the main objective of our study, we consider the extent to which arbitrage cost limits rational investors to fully offset the predictability of MAX stocks. We separate our entire sample into three separate samples of stocks based on IVOL. We then conduct Fama-Macbeth (1973) regression on the lowest IVOL (V1) and highest IVOL (V3) tercile portfolios. As mentioned earlier, if the high MAX to low realized return phenomenon is costly to arbitrage away, we expect the phenomenon to be concentrated on the sample of high IVOL stocks. Regression (3) and (4) of Table 6 presents results for the low IVOL stocks while regressions (5) and (6) present results for high IVOL stocks. The results suggest that the high MAX to low realized return documented by Bali, Cakici and Whitelaw (2011) is concentrated among high IVOL stocks. Specifically, for the high IVOL stocks, the estimated coefficients of MAX in the univariate and multivariate regressions are -0.044 and -0.024, and are statistically significant with *t*-statistics of -6.77 and -2.82 respectively. For low IVOL stocks, the corresponding estimated slopes of MAX are positive and significant with the inclusion of control variables. Particularly, we find that for low IVOL stocks, the estimated coefficients of MAX in both the univariate and multivariate regressions are 0.036 and 0.093, with Newey-West *t*-statistics of 1.86 and 3.58 respectively. In summary, our regression analysis on individual firms confirms the results we obtained from portfolio analysis and depicts that the negative relation between MAX and realized return exists predominantly among stocks with relatively high IVOL.

In Table 5, we document evidence from portfolio level analyses that the negative relation between daily MAX and the return in the following month is purely a non-January phenomenon for stocks with high IVOL. We verify this result within the context of cross-sectional firm-level Fama-MacBeth regressions. In the first two columns of Table 7, we report results for the entire sample differentiating between January and non-January months. For non-January months, we find a negative and significant relation between MAX and the cross-section of expected stock returns. In particular, the average slope coefficient on MAX is -0.031 with a *t*-statistic of -3.29. For January months, the relation between MAX and expected return is rather positive and statistically not different from zero. These regression findings support our results from portfolio level analyses that the negative MAX effect is purely a non-January occurrence. Our results are also consistent with Doran, Jiang and Peterson (2012) evidence that stocks with lottery-like features outperform in January and underperform in other months.

Table 7

Firm-Level Fama-MacBeth Cross-Sectional Regression :January vs Non-January

	Entire Sample		V1		V3	
	January	Non-January	January	Non-January	January	Non-January
	(1)	(2)	(3)	(4)	(5)	(6)
MAX	0.044	-0.031	0.085	0.093	0.046	-0.030
	(1.08)	(-3.29)	(1.19)	(3.40)	(1.36)	(-3.50)
SIZE	-0.423	-0.144	-0.263	-0.064	-1.044	-0.486
	(-5.37)	(-2.98)	(-5.08)	(-1.75)	(-6.31)	(-6.41)
BETA	-0.058	0.005	0.166	0.134	-0.036	0.011
	(-0.72)	(0.20)	(2.11)	(3.76)	(-0.41)	(0.52)
B/M	0.047	0.161	0.109	0.087	-0.012	0.142
	(0.32)	(2.96)	(0.80)	(1.45)	(-0.06)	(2.28)
ILLIQ	0.028	0.030	0.007	-0.001	0.034	0.036
	(1.26)	(4.83)	(0.22)	(-0.04)	(0.96)	(4.33)
REV	-0.059	-0.068	-0.054	-0.074	-0.062	-0.068
	(-4.88)	(-10.65)	(-3.57)	(-8.76)	(-4.62)	(-10.08)
MOM	0.598	0.561	0.598	0.721	0.721	0.572
	(1.71)	(2.83)	(1.05)	(4.54)	(2.59)	(2.04)
COSKEW	0.201	0.156	0.003	0.095	0.271	0.130
	(3.03)	(1.81)	(0.01)	(0.71)	(2.51)	(1.72)
ISKEW	-0.089	0.142	0.011	0.072	-0.179	0.143
	(-0.76)	(5.32)	(0.19)	(3.05)	(-1.14)	(3.15)

Note. This table reports the results of Fama-MacBeth cross-sectional regression of individual firms' returns in month $t + 1$ on control variables in month t. Stocks from NYSE, AMEX, and NASDAQ with at least 12 daily observations in each month t are included in the regression from January 1965 to December 2012. Each month t, stocks are grouped into tercile portfolios on IVOL. V1 (V3) is the lowest (highest) tercile portfolio on IVOL. MAX is maximum daily return in month t. BETA is the market beta. B/M is the book-to-market ratio. ILLIQ is illiquidity measure scaled by 100,000. REV is monthly return in the current month t when decile portfolios are formed. MOM is return from t -12 to t -1. COSKEW is a measure for coskewness. ISKEW is idiosyncratic skewness. IVOL is idiosyncratic volatility. The detailed explanations are provided in the main text. Newey-West (1987) adjusted t-statistics are reported in parentheses.

Next, we examine the extent of arbitrage costs inhibiting investors to arbitrage away the non-January high MAX to low return occurrence. We form tercile portfolio for each month based on IVOL. We then run separate Fama-MacBeth regression for both the high IVOL (V3) and low IVOL (V1) tercile group. In the last four columns of Table 7, we report results using low IVOL (regression (3) and (4)) and high IVOL (regression (5) and (6)) stocks for January and non-January months separately. We find that for the sample of Low IVOL stocks, there is no negative MAX effect irrespective of whether the period is January or non-January months. For January, the average slope coefficient on MAX is 0.085 and is statistically not different from zero with a *t*-statistic of 1.19. For non-January, the estimated coefficient of MAX is 0.093 and is statistically significant with *t*-statistic of 3.40.

For the sample of High IVOL stocks, we find a non-January MAX effect. In particular, the estimated coefficient of MAX for high-IVOL stocks in non-January month in regression (6) is -0.030 and is highly significant with *t*-statistic of -3.50. The corresponding estimated coefficient of MAX for high-IVOL stocks in January month in regression (5) is rather positive with an estimated MAX slope of 0.046 which is statistically not different from zero with a *t*-statistic of 1.36. Overall, these results show that the negative relation between daily MAX and return in the following month is a non-January phenomenon and exists mainly among stocks with relatively high IVOL.

Considering Investor Sentiment

In a recent study, Fong and Toh (2014) document that the MAX effect can be explain by investor sentiment. More precisely, they show that the high MAX to low realized return phenomenon can be observed only if the investor sentiment is high in the month when portfolios are formed on MAX. We investigate if IVOL has incremental explanatory power beyond investor sentiment in explaining the MAX effect. We use investor sentiment data from July 1965 to December 2010 to separate all months into low and high sentiment month where low (high) sentiment is the months below (above) median sentiment. We grouped stocks into tercile portfolios on IVOL for each month, and formed decile portfolios based on MAX. Panel A of Table 8 reports results using the entire sample.

Table 8

Average Returns of Portfolios Formed on MAX Across Investor Sentiment and Idiosyncratic Volatilities

	Panel A: Entire Sample				Panel B: V1				Panel C: V3			
	Value-Weighted Returns		Equal-Weighted Returns		Value-Weighted Returns		Equal-Weighted Returns		Value-Weighted Returns		Equal-Weighted Returns	
	Low Sent	High Sent	Low Sent	High Sent	Low Sent	High Sent	Low Sent	High Sent	Low Sent	High Sent	Low Sent	High Sent
Low MAX	0.57	1.04	1.29	1.10	0.72	0.73	1.27	0.81	1.03	0.18	3.15	1.62
2	0.69	1.14	1.27	1.38	0.61	1.07	0.84	1.28	1.06	-0.10	2.34	0.72
3	0.74	1.05	1.52	1.41	0.66	1.06	1.17	1.34	1.41	-0.48	2.23	0.42
4	1.02	0.94	1.62	1.27	0.77	1.13	1.20	1.34	1.24	-0.14	2.15	0.48
5	1.09	0.82	1.72	1.12	0.61	1.20	1.28	1.36	1.36	-0.17	1.93	0.35
6	1.23	0.79	1.83	0.94	0.75	1.29	1.21	1.36	1.10	-0.69	1.80	0.21
7	1.36	0.48	1.88	0.73	0.65	1.09	1.23	1.33	1.34	-0.62	1.98	-0.13
8	1.23	0.35	2.01	0.54	0.73	0.95	1.30	1.30	1.01	-0.60	1.66	-0.43
9	1.33	-0.33	1.88	0.21	0.88	0.81	1.24	1.16	1.09	-1.12	1.62	-0.25
High MAX	0.96	-0.84	1.68	-0.39	0.88	0.90	1.26	1.07	0.67	-1.31	1.77	-0.50
High - Low	0.39 (0.94)	-1.89 (-3.71)	0.39 (0.99)	-1.49 (-3.08)	0.16 (0.67)	0.17 (0.74)	-0.01 (-0.02)	0.26 (1.52)	-0.36 (-0.95)	-1.49 (-3.46)	-1.38 (-3.96)	-2.12 (-5.68)
Alpha	-0.24 (-0.74)	-1.86 (-4.44)	-0.20 (-0.72)	-1.29 (-2.46)	0.20 (0.77)	0.28 (1.22)	0.02 (0.15)	0.10 (0.64)	-0.28 (-0.62)	-1.80 (-4.10)	-1.43 (-4.05)	-2.22 (-5.70)

Note: This table reports the value- and equal-weighted average monthly returns of portfolios in month $t + 1$. Each month t, stocks are grouped into tercile portfolios on IVOL. V1 (V3) is the lowest (highest) tercile portfolio on IVOL. Then another decile portfolios are formed based on MAX (maximum daily return) each month t. Low (High) MAX is the portfolios of stocks with the lowest (highest) MAX in month t. Stocks from NYSE, AMEX, and NASDAQ with at least 12 daily observations in each month are included in the sample from January 1965 to December 2012. The investor sentiment data is from July 1965 to December 2010 and is downloaded from Wurgler's website. All months are separated into low and high sentiment month where low (high) sentiment is the months below (above) median sentiment. Alpha reports 4-factor (market beta, size, book-to-market, and momentum) alpha. Newey-West (1987) adjusted t-statistics are reported in parentheses.

Panel B and C of Table 8 produce results using stocks that belong to low (V1) and high (V3) tercile portfolio on IVOL, respectively. Table 8 reports the value- and equal-weighted average return for the following month for high and low sentiment months. The results for the entire sample in Panel A of Table 8 confirm the findings by Fong and Toh (2014); the negative relation between MAX and return in the following month is observed when portfolios are formed on MAX in high sentiment months. Following high sentiment months, the value-weighted (equal-weighted) return differences between high MAX and low MAX is -1.89% (-1.49%) per month and are statistically significant with *t*-statistic of -3.71 (-3.08). The difference between the four-factor alphas for high and low MAX is -1.86% (-1.29%) for value- (equal-) weighted return and is statistically significant with a *t*-statistic of -4.44 (-2.46). Following low sentiment months, there is no indication of a negative MAX effect as both the value- and equal-weighted return differences between high MAX and low MAX and their corresponding four-factor differences are statistically not different from zero. We find in Panel B and C that the finding of Fong and Toh (2014) depends on IVOL. The results using the low (high) IVOL sample refutes (confirm) the findings by Fong and Toh (2014). For low IVOL stocks, there is no MAX effect whether or not returns follow high sentiment months. For high IVOL stocks, we find the MAX effect following high sentiment months. Specifically, for high IVOL stocks, following high sentiment months, the value-weighted (equal-weighted) return differences between high MAX and low MAX is -1.49% (-2.12%) per month and are statistically significant with a *t*-statistic of -3.46 (-5.68). The four-factor alphas difference between the high and low MAX value-weighted (equal-weighted) portfolios are -1.80% (-2.22%) and are statistically significant with a *t*-statistic of -4.10 (-5.70). The results for high IVOL stocks following low sentiment months show no MAX effect in the case of value-weighted return. When return weighting scheme is equally-weighted, we find that MAX effect exist for high IVOL sample following low sentiment months. However, we find in Table 9 that the MAX effect in terms of equally-weighted returns following low sentiment months disappear after controlling for other variables.

In Table 8, we use portfolio level analyses to suggest that the effect of investor sentiment on the negative relation between MAX and return in the following month could be found only within high IVOL stocks. We verify this result using cross-sectional firm-level Fama-MacBeth regressions and report our results in Table 9. While regression (1) through (4) of Table 8 reports results using the entire sample, regression (5) through (8) and regression (9) through (12) of Table 9 show results using stocks that belong to low (V1) and high (V3) tercile portfolio on IVOL, respectively differentiating between low and high sentiment months. Following high investor sentiment months using the entire sample, we find in regression (3) and (4) a negative and significant relation between MAX and the cross-section of expected stock return. Univariate analysis determines the average slope coefficient on MAX is -0.063 with a *t*-statistic of -4.02. Controlling for other variables, the average slope of MAX is -0.049 with a *t*-statistic of -3.73. Following low sentiment months in regression (1) and (2), the relation between MAX and expected return is statistically not different from zero. These results further buttress Fong and Toh (2014) findings that MAX effect is driven by high investor sentiment.

Table 9

Firm-Level Fama-MacBeth Cross-Sectional Regression: Across Investor Sentiment and Idiosyncratic Volatilities

					Entire Sample		V1			V3		
			Low Sent	High Sent		Low Sent	High Sent		Low Sent	High Sent		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
MAX	0.001 (0.08)	-0.002 (-0.13)	-0.063 (-4.02)	-0.049 (-3.73)	0.043 (1.49)	0.149 (3.80)	0.033 (1.20)	0.044 (1.26)	-0.044 (-4.62)	-0.021 (-1.58)	-0.046 (-4.77)	-0.031 (-2.73)
SIZE		-0.269 (-4.11)		-0.084 (-1.21)		-0.142 (-2.84)		-0.019 (-0.37)		-0.598 (-5.62)		-0.523 (-5.01)
BETA		0.038 (1.14)		-0.040 (-0.96)		0.147 (2.83)		0.143 (3.23)		0.025 (0.88)		-0.009 (-0.27)
B/M		0.094 (1.33)		0.201 (2.41)		0.094 (1.33)		0.101 (1.19)		0.055 (0.71)		0.188 (1.94)
ILLIQ		0.023 (2.54)		0.034 (3.28)		0.012 (0.33)		-0.002 (-0.27)		0.023 (2.34)		0.047 (2.75)
REV		-0.083 (-8.38)		-0.054 (-8.74)		-0.085 (-6.92)		-0.062 (-6.10)		-0.083 (-7.67)		-0.054 (-8.59)
MOM		0.425 (1.17)		0.752 (4.89)		0.727 (2.47)		0.722 (4.45)		0.367 (0.72)		0.851 (5.01)
COSKEW		0.148 (1.27)		0.131 (1.35)		0.107 (1.24)		0.083 (0.41)		0.144 (1.35)		0.119 (1.13)
ISKEW		0.149 (4.05)		0.095 (2.20)		0.051 (1.72)		0.086 (2.60)		0.173 (3.09)		0.051 (0.94)

Note. This table reports the results of Fama-MacBeth cross-sectional regression of individual firms' returns in month $t + 1$ on control variables in month t across investor sentiment. Each month t, stocks are grouped into tercile portfolios on IVOL. V1 (V3) is the lowest (highest) tercile portfolio on IVOL. The investor sentiment data is from July 1965 to December 2010 and is downloaded from Wurgler's website. All months are separated into low and high sentiment month where low (high) sentiment is the months below (above) median sentiment. Stocks from NYSE, AMEX, and NASDAQ with at least 12 daily observations in each month t are included in the regression from January 1965 to December 2010. MAX is maximum daily return in month t. BETA is the market beta. B/M is the book-to-market ratio. ILLIQ is illiquidity measure scaled by 100,000. REV is monthly return in the current month t when decile portfolios are formed. MOM is return from t -12 to t -1. COSKEW is a measure for coskewness. ISKEW is idiosyncratic skewness. IVOL is idiosyncratic volatility. The detailed explanations are provided in the main text. Newey-West (1987) adjusted t-statistics are reported in parentheses.

When we run separate Fama-MacBeth regression for high IVOL and low IVOL portfolios, we confirm our portfolio level analysis findings that there is no MAX effect for low IVOL stocks in regression (5) through (8). In other words, for low-IVOL stocks, we find no significant relation between MAX and expected return regardless of whether returns follow from high or low sentiment months. For high-IVOL stocks, the univariate test suggests that MAX effect exists following low sentiment months; however, after controlling for other variables, MAX effect disappears following low sentiment months and is strong following high sentiment months. Controlling for other variables, the estimated coefficient of MAX for high-IVOL stocks following high sentiment (low sentiment) month is -0.031% (-0.021%) and is significant (insignificant) with a *t*-statistic of -2.73 (-1.58). We can therefore conclude that the effect of investor sentiment on the MAX effect depends on arbitrage risk.

CHAPTER FOUR

CONCLUSIONS

Bali, Cakici and Whitelaw (2011) document a negative and significant relation between maximum daily return over the past one month and expected stock returns. Their results suggest that a MAX strategy that shorts a value-weighted portfolio of low MAX and longs a value-weighted portfolio of high MAX stocks produces an average return of about -1.03% per month. A natural question is why this strategy is not exploited by arbitrageurs to make profit? This question is difficult to explore empirically as arbitrageurs are not at liberty to disclose much information about their strategies.

Using idiosyncratic volatility as a proxy for limits to arbitrage, we find that the high MAX to low return (known as the "MAX effect") exists because of high barriers to arbitrage. The MAX effect is observed predominantly on a sample with high arbitrage risk. In addition, we consider seasonality and find that the high MAX to low returns is a Non-January phenomenon that persists because of high arbitrage cost. Lastly, we consider recent findings by Fong and Toh (2014) that MAX effect is driven by high investors' sentiment, and we find that the role of investor's sentiment on the MAX effect depends on arbitrage risk. Our findings suggest that, at least in parts, the existence of the MAX effect is the result of arbitrage cost.

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