The MAX Effect: Lottery Stocks with Limit Hits and Limits to Arbitrage

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February 2017

Abstract

The maximum daily returns (MAX) over the prior month have been documented to be negatively associated with future stock returns. Due to the government regulator imposing limits on stock price, it is inadequate to calculate the extreme daily return in Taiwan. We modify the Bali, Cakici, and Whitelaw's (2011) MAX measure by solving the problem of homogeneous MAX across stocks. The results indicate that the modified MAX is a negative and significant predictor of future stock returns. The modified MAX effect is not a manifestation of the idiosyncratic volatility effect. The negative idiosyncratic volatility effect only exists in the stocks with high modified MAX, i.e., the overpriced side, indicating that our modified MAX measure is an alternative proxy for arbitrage risk.

Keywords: Extreme returns; lottery stock; idiosyncratic volatility; limits to arbitrage

JEL code: G11, G12, G17

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1. Introduction

Investors are more willing to accept negative expected returns for stocks with positively skewed returns. They have a preference to pick the stocks with realized high ratio of being upward. Since they have paid a higher price for stocks with a lottery-like payoff or greater skewness, the stocks experience negative returns in the subsequent period. Stocks with lottery-like payoff will be temporarily overpriced and earn negative risk-adjusted returns in the later period. Many studies have documented that cross-sectional variations in gambling characteristics for stocks are associated with future stock returns. For example, Kumar, Page, and Spalt (2011) show that investors' gambling preferences impact stock returns as well as corporate policies. Bali, Cakici, and Whitelaw (2011) adopt extreme positive returns (MAX) as a proxy for lottery-like feature and document a significantly negative relation between the maximum daily return during a month and future stock return.

The negative relation between MAX and future stock returns has been widely documented internationally. For example, Bali, Cakici, and Whitelaw (2011) first document the negative MAX effect in the US stock market. Walkshäusl (2014) show that the MAX is a significant and negative predictor of future stock returns in the European equity markets. Chan and Chui (2016) show that there is a lottery premium in the Hong Kong stock market. However, there is no study investigating the MAX effect in emerging markets. We contribute to the literature by exploring the MAX effect in a highly regulated market outside the United States. Our Taiwanese evidence provides a useful out-of-sample test on the negative MAX effect. Particularly, Taiwan has a larger portion of retail investors than other developed markets. The large fraction of individual investors is more like to induce gambling premium (Han and

Kumar, 2013).[1]

Unlike many mature markets, due to the regulation of price limit imposed in the Taiwan Stock Exchange, the maximum daily return within a month is inaccessible. The maximum daily return during a month is the same across all stocks.[2] We propose a modified measure regarding the extreme daily return within a month. We use the frequency of limit hits to proxy for the maximum daily return within a month. Specifically, since calculating the daily maximum return by daily price changes is inappropriate to measure lottery-type feature, we use intensity of upward limit hit of a month to proxy for the potentially positive skewness facing investors. We argue that instead of extreme daily return, the frequency of daily upward limit hits attract gambling investors' attention.[3] Intuitively, gambling investors prefer to bet on stocks with many upward limit hits and avoid holding stocks with many downward limit hits. Our modified MAX is defined as the difference between upward limit-hitting rates and downward limit-hitting rates. For each month *t*, we use the 80th percentile as the breakpoint to classify firms into highest and lowest modified MAX groups. The paper contributes to the literature by suggesting an alternative way of categorizing potential lottery-like stocks in markets with price regulations. The evidence shows that our modified MAX better captures the gambling demand in stocks than traditional MAX measure based on daily price changes.

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[1] According to the Fact Book of the Taiwan Stock Exchange, in 2000, the fraction of individual trading is about 86%, and recently, in 2015, the fraction of individual investors drops to 56%.

[2] The Taiwan stock market has changed the regulation of price limit several times. Appendix B reports the dates of changes of price limit. The all of changes are downward limit, suggesting that regulator tend to narrow down the downward limit to 3.5% to prevent from over selling pressure during the panic periods. Recently, the daily price limit has been widened from 7% to 10% after June 1st, 2015.

[3] Seasholes and Wu (2007) document that the stocks with upward limit hit will attract investors to purchase the stocks they have not previously owned. Lin, Ko, Chen, and Chu (2016) use price limits as a measure representing attention-grabbing events in Taiwan. They indicate that attention is a necessary condition for investors' overconfidence.

Specifically, due to the regulation of price limit imposed in the Taiwan Stock Exchange, the Bali, Cakici, and Whitelaw's (2011) MAX effect does not exist in the Taiwan stock market. On the other hand, there is a significantly negative relation between modified MAX and future stock returns. The stocks with highest (lowest) modified MAX experience lower (higher) future returns, indicating that stocks with highest (lowest) modified MAX tend to be overpriced (underpriced). The sub-period tests indicate a stronger modified MAX effect in the later period than in earlier period. Our modified MAX effect is stronger during optimistic periods than during pessimistic periods, which is consistent with the argument that the investor optimism creates a preference for lottery-type stocks (Fong and Toh, 2014).

Portfolios held by individual investors are not well-diversified (Bali, Cakici, and Whitelaw, 2011; Calvet, Campbell, and Sodini, 2007; Mitton and Vorkink, 2007; Goetzmann and Kumar, 2008; Barber and Odean, 1999). Particularly, Bali, Cakici, and Whitelaw (2011) suggest that because of preference to lottery-type stocks, the individual investors are lacks of diversification, i.e., individual investors' lottery demand causes the negative idiosyncratic volatility premium. They show that after controlling for the MAX, the negative effect of idiosyncratic volatility on stock returns disappears. Kumar (2009) also indicates that the stocks with the lottery-type feature, which is defined as low-priced, will exhibit high idiosyncratic volatility. Consistent with these two studies, our modified MAX effect is highly related to idiosyncratic volatility. Gu, Kang, and Xu (2016) show that the negative IVOL effect is mainly due to limits-to-arbitrage in the China stock market. Consistent with Gu, Kang, and Xu (2016), we show that the negative idiosyncratic volatility effect only exists in the stocks with high modified MAX, i.e., the overpriced side, suggesting that our modified MAX is an alternative proxy for limits to arbitrage.

2. Data and Descriptive Statistics

From January 1990 to December 2016, the daily stock prices, market (TAIEX) returns (including dividends), and stock trading data are obtained from a commercial database maintained by the Taiwan Economic Journal (TEJ). The accounting data and the outstanding shares of listed firms are also available in TEJ. The database includes all currently and historically listed common stocks on the Taiwan Security Exchange Commission. During most of our sample period, daily price limit for each stock is set at ± 7 percent from the stock's previous closing. More precisely, the stock is categorized as limit hitting if its price is at its limit or less than one tick from its limit. Stocks with less than ten trading days during a month are excluded. We use daily data for calculating the intensity of limit hits of each stock and each month and monthly data for asset pricing tests.

Table 1 provides the descriptive statistics for firm characteristics used in this paper. The average Bali's MAX (*MAX5*) of our sample of 2.94% is relatively low compared to another developed market without price limit regulation, such as Hong Kong. Chan and Chui (2016) report the Hong Kong's average *MAX5* of 4.13%. Further, the 90th percentile of *MAX5* in Hong Kong is 7.57%. However, in Taiwan, it is 5.36% which is apparently lower than the regime of the price limit, i.e., 7%, suggesting that price limits have blocked the true *MAX5* in Taiwan. Panel B shows that the *MAX5* is highly correlated with idiosyncratic volatility (*IVOL*) 0.78, the ratio of upward limit hits (*UPR*) 0.70, turnover ratio (*LnTU*) 0.51, and reversal (*PR01*) 0.47.

[Table 1 here]

3. MAX Portfolios

First, following Bali, Cakici, and Whitelaw (2011), we use the average of the highest five daily returns (*MAX5*) in month *t* to proxy for the lottery-like feature. Chan and Chui (2016) show that the *MAX5* has the strongest MAX effect in predicting future stock returns. For example, Bali, Brown, Murray, and Tang (2016) document that using the *MAX5* as the lottery proxy can capture the investors' gambling demand for negative relation between beta and future stock returns.

Specifically, for each stock at the end of month *t*, we calculate its prior one month *MAX5* and sort all stocks into deciles based on *MAX5*. The portfolios are held for one month, and portfolio returns are equally and value weighted. We construct a zero-investment portfolio that long buys stocks with the highest *MAX5* and short sells stocks with lowest *MAX5*. The performances of the portfolios are compared by raw returns and Fama-French (1993) alphas.[4] The results of Table 2 indicate that the relation between *MAX5* and future stock returns is negative, however, insignificant either in raw returns or alphas. For instance, the zero-investment portfolios of highest *MAX5* group minus lowest *MAX5* group are all insignificantly negative.

The following reasons explain why *MAX5* might not be an adequate measure to proxy for the lottery-like feature in the Taiwan stock market. Frist, Table 1 of Bali, Cakici, and Whitelaw (2011) indicates that the average highest daily return is about

[4] Following Fama and French (1993), HML and SMB are constructed as follows. At the beginning of each July from 1991 to 2016, all stocks are allocated to two size groups (small and big, S and B) based on whether their June market equity is below or above the median market equity. Then, all stocks are independently allocated to three BM groups (low, medium, and high; L, M, and H) based on the breakpoints for the bottom 30 percent, middle 40 per cent, and top 30 percent of the values of BM. Six size/BM portfolios (S/L, S/M, S/H, B/L, B/M, and B/H) are constructed from the intersections of the two size and the three BM groups. The value-weighted returns on them are calculated from July to the next June, the first 12 months after formation. The portfolio return HML is the difference between the average returns on the S/H and the B/H portfolios and the average returns on the S/L and the B/L portfolios. Similarly, the SMB is the difference between the average returns on the S/L, S/M, and S/H portfolios and the average returns on the B/L, B/M, and B/H portfolios.

23.6% in the US stock market. Our Panel B shows that the average highest five daily returns within a month is about 5.75% for the highest *MAX5* group. The magnitude of average daily return in Taiwan is relatively low. On the other hand, the average daily return for the lowest group in the US is about 1.30% (Bali, Cakici, and Whitelaw, 2011). The number of *MAX5* in our lowest group is about 1.02% which is quite similar to the past results.

Second, the highest portfolio experience on average 3.3 days of upward limit hits of a month. That is, there are very likely that the five highest daily returns during the month are also upper limit hits. The *MAX5* underestimates the true extreme daily performance of firms with multiple upper limit hits. For example, if five highest daily returns during the month are all limit hits, then the average daily return is just the price limit, i.e., 7%. As a result, *MAX5* might not truly reflect the characteristic of skewness of lottery-like feature. Most importantly, gambling investors' attention will not be attracted by extreme daily returns in Taiwan, since the extreme daily returns are very the same across stocks.

[Table 2 here]

4. Modified MAX Portfolios

Unlike many mature markets, such as US stock market, due to the regulation of price limit imposed in the Taiwan Stock Exchange, the maximum daily return during a month is the same across all stocks.

We propose a modified MAX measure regarding the extreme daily return within a month. We use the intensity of limit hits to proxy for the maximum daily return within a month. Specifically, for each stock at the end of month *t*, we calculate its prior one month upward (downward) limit-hitting rates (the number of trading days hitting the upper (lower) price limit divided by a total number of trading days during a month). We argue that gambling investors will bet on stocks with high intensity of upward limit hits and avoid holding stocks with downward limit hits. The modified MAX measure (*LHR*) is defined as the difference between upward limit-hitting rates and downward limit-hitting rates. Since the distribution of *LHR* of all stocks is right skewed, that is most of the firms have *LHR* close to zero, for each month *t*, we use the 80^{th} percentile as the breakpoints to classify firms into highest and lowest modified MAX groups.

Table 3 shows that the stocks with highest (lowest) modified MAX (*LHR*) experience lower (higher) future returns, indicating that stocks with highest (lowest) modified MAX (*LHR*) tend to be overpriced (underpriced). The average difference between equally-weighted (value- weighted) returns on portfolios with the highest *LHR* and lowest *LHR* is -0.843% (-0.870%) per month. The corresponding equally-weighted (value-weighted) Fama- French three-factor alpha is -0.690% (-0.727%) per month. Both return differences are statistically significant. The evidence indicates that the stocks with the highest modified MAX (*LHR*) tend to be over-priced and stocks with the lowest modified MAX (*LHR*) tend to be underpriced.

Panel B presents the average selected characteristics for the highest *LHR* and the lowest *LHR* portfolios. The results show that the stock with the highest *LHR* tends to be higher turnover, lower illiquidity, higher idiosyncratic volatility, lower market beta, higher *MAX5*, higher price-to-book ratio, higher reversal, lower momentum. In the following sections, we will further explore the robustness checks of whether our modified MAX (*LHR*) is driven by those important variables in determining future stock returns.

[Table 3 here]

5. Cross-Sectional Regressions

We apply Fama-MacBeth cross-sectional regression to test the relation between modified MAX (*LHR*) and future stock returns. The regressions include controlling variables that measure market capitalization, price-to-book ratio, prior returns, liquidity, and volatilities. From January 1990 to December 2016, for each month, we cross-sectionally regress returns on independent variables by OLS. The time-series averages are calculated from the cross-sectional estimates of these firm characteristics. Average parameter values are the time series averages, and *t*-statistics are the time-series averages divided by the time-series standard errors. The *t*-statistics are adjusted by a Newey-West method with 12 lags.

Table 4 indicates that the modified MAX (*LHR*) is significantly and negatively related to future monthly returns. However, consistent with results of the previous section, the *MAX5* is insignificantly negative. After controlling for several important characteristics, the coefficient on *LHR* is statistically significant of -5.823 (*t*-statistics = -4.78).

IVOL is significantly negative when *IVOL* is included in the specification. Further, the coefficient on *IVOL* remains negative and highly significant when January is excluded. The coefficient on the turnover ratio is negative and significant at the 1% level. Moreover, the coefficients on reversal factor (*PR01*) and momentum factor (*PR12*) are significantly positive.

We also perform tests including or excluding the January coefficients since prior studies show that excluding January makes the effects of beta, size, and the bid-ask spread insignificant (e.g., Keim, 1983; Tinic and West, 1986; Eleswarapu and Reinganum, 1993). Inconsistent with prior studies, the results show that the reversal effects, such as *LHR*, *IVOL*, and *LnTU*, only exist in non-January period. However, due to small sample size and lacks of statistical power, we do not find any evidence that *LHR* is particularly significant in January.

[Table 4 here]

6. Sub-Periods Test

Under our sample period, there are many significant changes in price limit regime due to certain unusual events, for example, recently, the Taiwan Stock Exchange has raised daily price fluctuation limit from 7 to 10% since June 1st, 2015. The changes in price limit regimes raise the concern that the time-series event may drive the results. To address this concern, we split the sample into different periods. Table 5 shows the Fama-MacBeth regression coefficients based on different partitions of the sample period.

Models 1 to 3 are based on three sample periods from distant to recent. The results show that the modified MAX effect (*LHR*) becomes stronger in the later period than in the earlier period. The modified MAX effect is insignificantly negative during the earlier period of before 2000. However, the coefficient of modified MAX (*LHR*) in the period after 2009 is almost four times larger than that during the period before 2000. Thus, we can conclude that the modified MAX effect exists after 2000. For rest of relevant variables, the coefficients on Bali's MAX (*MAX5*) are all insignificant for three partitions of the sample period. The *IVOL* effect is particularly stronger in the period during 2000 to 2009. However, *IVOL* effect is absent during the recent period (after 2009 period). Similar to the result of modified MAX, the turnover ratio exhibit a significantly negative predictive ability of future stock returns during the recent period (after 2009 period). Surprisingly, the reversal factor (*PR01*) does not exhibit any reversal ability on stock returns. However, after 2009, the *PR01* has a positive relation with the future stock returns, and the momentum effect (*PR12*) only exists in the most recent periods, i.e., after 2000 periods.

It seems reasonable to expect that the gambling behavior is particularly strong during optimistic periods. We use three types of classifications to split the sample into optimistic and pessimistic periods. They are market return, business cycles indicator, and investors' sentiments. The market return is calculated by the Taiwan Stock Exchange Index. We use monthly business cycle indicators provided by the Taiwan National Development Council. We use consumer confidence index to proxy for investors' sentiment (Antoniou et al. 2013), and the data is provided by the National Central University.[5] The up (down) market months are defined as the periods where market returns are positive (negative). We define month *t* as expansion (recession) if the value of business cycle indicator in month *t* is greater (lower) than 22 points. The month *t* is defined as high (low) sentiment if the score of consumer confidence is higher than 75 points. 22 points and 75 points are the median values of business cycle indicator and consumer confidence index over the period from January 2001 to December 2016.

Models 4 to 9 show the results. First, modified MAX (*LHR*) is significantly negative for all classifications of periods. Second, the unreported results document that coefficients on modified MAX (*LHR*) during upmarket, expansion, and high investors' sentiment, are greater than those during down market, recession, and low investors' sentiment. The investors' gambling demand, *LHR*, is particularly higher in optimistic periods.

[Table 5 here]

[5] Data of business cycle indicators are assessed from the http://index.ndc.gov.tw/n/en. The data of investors' sentiment is from http://rcted.ncu.edu.tw.

7. Limits to Arbitrage

To clarify the explanation of the existence of the modified MAX (*LHR*) effect, we form two-dimensional sequentially-sorted portfolios based on stock characteristics and *LHR*. First, we separate stocks into three groups by a given measure of stocks' characteristics. Second, within each characteristics group, we further divide stocks into high and low groups by *LHR*.

According to the efficient market hypothesis, if a stock is mispriced, the potential profits embedded in the stock will attract rational investors, and their trading should immediately correct the misprice. However, in a realistic world, the arbitrage is costly and risky. As a result, the mispricing stocks might exist longer when the limits-to-arbitrage are more severe. We use the following stock characteristics to proxy for limits-to-arbitrage: market capitalization, Amihud (2002) illiquidity, and idiosyncratic volatility. The portfolios are held for one month. In addition to raw returns, the returns are adjusted for Fama-French three factors. The detailed definitions of each variable are shown in Appendix A.

Table 5 of Panel A shows the returns on *LHR* separated into size tercile subsamples. The results indicate that for all types of performances, equal-weighted, value-weighted, raw returns, and alphas, the modified MAX premium is particularly pronounced in a group of small market capitalization. There is no profitability for the medium and large groups of stocks. The alphas for the stocks in high modified MAX portfolio are insignificantly negative. The equal- or value-weighted raw and abnormal returns of the stocks with low modified MAX are all significantly positive at the 1% level. Thus, the profits of zero-cost portfolio mainly come from long leg of the portfolio, i.e., the low modified MAX portfolio.

Panel B provides the results based on tercile subsamples of Amihud (2002) illiquidity. Similarly, the modified MAX premium is almost nonexistent in a group of low illiquidity. However, the alpha earned by shorting the highest modified MAX stocks is about 80 basis points per month which is at 5% level of significance. On the other hand, for medium and large illiquidity groups, the profits of the zero-cost strategy mainly come from long purchasing the lowest modified MAX stocks. For example, for high illiquidity group, the value-weighted abnormal returns on the low MAX portfolio is about 1.52% per month, takes about 92% (1.52/1.66) of total hedged profits. Since the modified MAX strategy is a contrarian strategy, i.e., investors of the contrarian strategy long buy undervalued stocks and short selling overvalued stocks. The investors adopting contrarian strategy should not face serious transaction cost than momentum traders since contrarian trader is a liquidity provider rather than liquidity demander.

Although the main component of profits comes from undervalued stocks, i.e., long position or the stocks with the lowest modified MAX, the arbitrageurs of undervalued securities might also face risks of noise trader momentum risk. Specifically, according to Barberis and Thaler (2003), is the risk that irrational beliefs get worse in the direction already distorting prices. The unique bad news about the fundamental of undervalued stock will cause the stock continue to fall further. As a result, it is important to examine if the undervalued stocks (the stocks with lowest modified MAX) have particularly high individual unique risks. Prior studies use *IVOL* to proxy for arbitrage risk, i.e., the measure of hard to value and difficult to arbitrage (Shleifer and Vishny, 1997). We attempt to explore whether high *IVOL* securities will exhibit greater mispricing and a higher average return to arbitrage (Stambaugh, Yu, and Yuan, 2012). The modified MAX effect conditional on various idiosyncratic volatility is shown in Panel C. The modified MAX premium is nonexistent in lowest and medium idiosyncratic volatility groups. However, the modified MAX premium is significantly negative for the highest *IVOL* group. For example, the value-weighted alpha of modified MAX is about 100 BP per month at 5% level of significance.

[Table 6 here]

Based on above discussions, it is important to examine whether our modified MAX effect is dominated by size premium, illiquidity premium, and idiosyncratic volatility premium. We regress the modified MAX premium on size premium (*MV*), illiquidity premium (*ILLQ*), and idiosyncratic volatility (*IVOL*) premium. We use the following procedure to make the sign of each premium the same, i.e., positive premium. The *ILLQ* premium is constructed by long buying the highest *ILLQ* and short selling the lowest *ILLQ* portfolio. The rest of premiums adopt long buying the lowest portfolio and short selling the highest portfolio. Except for the modified MAX (*LHR*), we independently sort all stocks into ten groups based on each variable, separately. The Group 1 (10) is defined as the lowest (highest) portfolio.

Panel A shows that the modified MAX premium has no relation to size premium and has a moderate relation with illiquidity premium. Consistent with prior studies, our modified MAX premium has a strong association with idiosyncratic volatility premium. The result is not only statistically significant but also economically significant. For instance, in Model 2 of Panel A, the coefficient on *IVOL premium* is 0.445, that means one standard deviation increase in monthly *IVOL premium* will raise the modified MAX premium about 2.7% per month. The results confirm the argument of Barberis and Thaler (2003) that the undervalued stocks also exhibit higher undiversified arbitrage risks. However, the intercepts for all models in Panel A are all significantly positive, indicating that the three measures of limits-to-arbitrage cannot fully account for the modified MAX premium. Second, when we use modified

MAX premium as an independent variable to explain three limits-to-arbitrage measures in Panel B, noteworthy is that the intercept of *IVOL premium* becomes insignificant. That is, our modified MAX premium can capture the *IVOL premium*. However, in contrast, the IVOL premium can only partially explain the modified MAX premium.

[Table 7 here]

In Table 8, we further examine the relation between the modified MAX and *IVOL*. We try to test if our modified MAX measure also plays the same role as *IVOL* in measuring arbitrage risk. Following the procedure of Gu, Kang, and Xu's (2016), we presume that our modified MAX is a proxy of arbitrage risk, and underlying strategy is the idiosyncratic volatility strategy. If our modified MAX does represent the magnitude of limits-to-arbitrage, then we shall see that the *IVOL* strategy can only present in the group of high modified MAX.

Similarly, we sequentially sort stocks into modified MAX and then idiosyncratic volatility portfolios. We first sort stocks into high and low modified MAX (*LHR*) by using 80^{th} percentile as a breakpoint. Then within each modified MAX group, we further sort stocks into ten groups based on *IVOL*. We test if *IVOL* effect presents after controlling for the modified MAX. Consistent with Gu, Kang, and Xu's (2016) finding in China, the negative *IVOL* effect only presents in the group of high modified MAX group which is the overpriced stocks. Moreover, consistent with Bali and Cakici (2008), the negative *IVOL* effect is stronger when returns are value-weighted. The value-weighted alpha for the zero-cost portfolio is 95 BP per month. Similar to the results of modified MAX portfolio, above half of the profits of zero-cost *IVOL* strategy come from long position, i.e., the low *IVOL* portfolio. The differences in *IVOL* premium between low and high modified MAX groups are all significant positive. In sum, the results are consistent with our argument that the modified MAX is also a proxy for arbitrage risk.

[Table 8 here]

8. Conclusions

Prior studies have documented that extreme returns are negatively associated with future stock returns. However, there are price regulations in several emerging equity markets, such as the Taiwan Stock Exchange. Due to price-limit regulation, the maximum daily returns within a calendar month are almost the same for all firms. In this paper, we provide a method that modifies the original MAX measure and overcome the problem of homogeneous MAX caused by price regulation. The modified MAX can negatively predict future stock returns and is more suitable than original MAX measure in capturing the investors' gambling demand in Taiwan. The stocks with highest (lowest) modified MAX experience lower (higher) future returns, indicating that stocks with highest (lowest) modified MAX tend to be overpriced (underpriced). The modified MAX effect is stronger during optimistic periods than during pessimistic periods. The modified MAX effect is closely related to idiosyncratic volatility. The modified MAX premium is able to capture the idiosyncratic volatility premium. We suggest that the modified MAX is an alternative proxy for limits to arbitrage.

Appendix A. Variable Definitions

1. Extreme returns (MAX5)

Following Bali, Cakici, and Whitelaw (2011), we use the average of the five highest daily returns during the month to calculate extreme returns.

2. Modified extreme returns* (*LHR)

It is defined as the difference between upward limit-hitting rates and downward limit-hitting rates. For each month t, we use the 80^{th} percentile as the breakpoints to classify firms into highest and lowest *LHR* groups. We use *LHR* to proxy for the modified MAX.

3. *Idiosyncratic Volatility* (*IVOL*)

We measured idiosyncratic volatility each month as the standard deviation of the residual returns from the Fama–French three-factor model by regressing the daily returns of individual stocks in excess of the one-month Bank of Taiwan deposit rate on the daily returns to the common factors related to market, size, and book-to-market ratio. We required a minimum of 15 observations for model estimation.

4. *Systematic Risk* (*Beta*)

For each firm and month, we estimate systematic risk by regressing daily excess returns on market risk premium.

5. *Size* (*MV, millions*)

MV is defined as the market value of equity at the month-end prior to the portfolio formation.

6. *Prior Returns* (*PR*)

PR is defined as one month return of firm at the month-end prior to the portfolio formation.

***7. Turnover* (*TURN*)**

TR is denoted as the month-end prior to the portfolio formation, turnover is the ratio of monthly trading volume to shares outstanding.

8. *Price-to-Book Equity* (*PB*)

PB is denoted as the stock price scaled by book equity per share as reported at the end of the most recent fiscal year.

9. Amihud Illiquidity (ILLQ)

According to Amihud (2002), illiquidity measure is the average ratio of the daily absolute return to the dollar trading volume on that day. The measure is multiplied by 10^6.

10. Relative Bid-Ask Spread (BASK)

It is the average ratio of daily bid-ask spread divided by the daily (Bid + Ask)/2 in the month.

Appendix B. Time-Varying Regulation of Limit Hits

Time			Upper limit	Lower limit	Descriptions
10/11/1989	~	9/26/1999	7.00%	7.00%	
9/27/1999	~	10/10/1999	7.00%	3.50%	Catastrophe: earthquake
10/11/1999	~	3/19/2000	7.00%	7.00%	
3/20/2000	~	3/21/2000	7.00%	3.50%	Political risk
3/22/2000	~	10/3/2000	7.00%	7.00%	
10/4/2000	~	10/11/2000	7.00%	3.50%	Political risk
10/12/2000	~	10/19/2000	7.00%	7.00%	
10/20/2000	~	11/7/2000	7.00%	3.50%	Financial crisis
11/8/2000	~	11/20/2000	7.00%	7.00%	
11/21/2000	~	12/31/2000	7.00%	3.50%	Political risk
1/1/2001	~	9/18/2001	7.00%	7.00%	
9/19/2001	~	9/22/2001	7.00%	3.50%	Catastrophe: hurricane
9/23/2001	~	5/31/2015	7.00%	7.00%	
6/1/2015		Current	10.00%	10.00%	

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Table 1

Descriptive Statistics and Correlations among Firm Characteristics

Panel A presents the summary statistics for firm characteristics. The detailed definitions of firm characteristic are shown in the Appendix A. Panel B presents the Person correlation among variables. We take the logarithm of market value (*LnMV*), the price-to-book ratio (*LnPB*), and turnover ratio (*LnTU*). *UP* (*ALL*) is the frequency of upward (upward plus downward) limit hits.

Panel A: Summary statistics	Mean	Std.	10th Pct.	Median	90th Pct.
MAX5 (%)	2.940	1.619	1.088	2.626	5.362
UPR (%)	3.153	6.391	0.000	0.000	9.524
LHR (%)	1.286	6.711	-4.167	0.000	8.333
UP (Frequency)	2	2	1	1	4
ALL (Frequency)	1	2	0	0	3
MV (NTD millions)	24609	103533	1131	5422	41258
PB	1.801	2.569	0.620	1.330	3.320
TURN(%)	16.977	23.232	1.160	8.550	43.241
BETA	0.810	0.650	0.080	0.790	1.575
IVOL(%)	1.630	0.837	0.696	1.486	2.758
ILLQ	0.984	4.116	0.009	0.100	1.433
BASK	0.006	0.006	0.002	0.004	0.009
PR01(%)	0.872	13.544	-13.158	0.000	15.190
PR12(%)	10.737	54.384	-39.230	1.189	67.012

Panel B: Person correlations

	LnPB	*LnTU*	*MAX5*	*BETA*	*IVOL*	*ILLQ*	*BASK*	*UPR*	*LHR*	*PR01*	*PR12*
LnMV	0.44	0.09	-0.08	0.12	-0.19	-0.29	-0.40	-0.13	-0.03	0.05	0.15
LnPB		0.32	0.07	0.03	0.02	-0.12	-0.12	0.00	0.08	0.13	0.37
LnTU			0.51	0.16	0.41	-0.24	-0.24	0.32	0.19	0.21	0.28
MAX5				0.16	0.78	0.05	0.15	0.70	0.42	0.47	0.06
BETA					0.07	-0.07	-0.08	0.07	0.01	-0.05	0.05
IVOL						0.13	0.24	0.55	0.26	0.24	0.10
ILLQ							0.61	0.04	-0.02	-0.03	-0.08
BASK								0.15	0.02	-0.03	-0.08
UPR									0.70	0.50	0.02
LHR										0.68	0.03
PR01											0.01

Table 2

MAX Portfolios

The table reports the average returns (*Raw returns*) and Fama and French three factor adjusted returns (*alpha*). From January 1990 to December 2016, for each month *t*, we use prior one month's five average highest daily return (*MAX5)* to sort all stocks into ten groups, portfolio highest contains stocks in Group 10, and the portfolio lowest include the stocks in Group 1. The spread portfolio (H-L) is constructed as long buying high MAX stocks and short selling the low MAX stocks. The portfolios are held for one month and rebalanced for each month, and the portfolio returns are either equally or value-weighted. Panel B reports the average firm characteristics. UP is the frequency of upward limit hit. The detailed definitions of the rest of variables are shown in Appendix A. The *t* ratios are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. We take the logarithm of market value (*LnMV*), the price-to-book ratio (*LnPB*), and turnover ratio (*LnTU*).

Panel A: Average returns	*Lowest*	*Highest*	*H-L*
EW Raw	0.564	0.521	-0.043
	(1.54)	(0.86)	(-0.11)
EW alpha	0.080	-0.082	-0.163
	(0.51)	(-0.34)	(-0.52)
VW Raw	0.504	0.480	-0.024
	(1.40)	(0.80)	(-0.06)
VW alpha	0.025	-0.104	-0.129
	(0.16)	(-0.43)	(-0.41)
Panel B: Characteristics			
MAX5	1.020	5.757	4.737
UP	1.062	3.302	2.240
BETA	0.385	1.002	0.618
IVOL	0.800	2.969	2.169
LnMV	8.654	8.342	-0.313
LnPB	0.264	0.484	0.220
LnTU	1.100	3.139	2.039
ILLQ	1.062	1.619	0.557
BASK	0.005	0.008	0.002
PR01	-0.041	0.163	0.203
PR12	0.040	0.214	0.174

Table 3

Modified MAX Portfolios

The table reports the average returns (*Raw returns*) and Fama and French three factor adjusted returns (*alpha*). We use *LHR* to proxy for modified MAX measure. From January 1990 to December 2016, for each month *t*, we use prior one month's modified MAX measure to sort all stocks into ten groups. The *LHR* is defined as the difference between upward limit-hitting rates and downward limit-hitting rates. Portfolio highest contains stocks in Groups 10 and 9, and the portfolio lowest include the rest of stocks. The spread portfolio (H-L) is constructed as long buying high modified MAX stocks and short selling the low modified MAX stocks. The portfolios are held for one month and rebalanced for each month, and the portfolio returns are either equally or value-weighted. Panel B reports the average firm characteristics. The detailed definitions of the variables are shown in Appendix A. The *t* ratios are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Average returns	*Lowest*	*Highest*	*H-L*
EW Raw	0.89**	0.39	-0.50**
	(1.97)	(0.69)	(-1.99)
EW alpha	0.85**	0.34	-0.51**
	(1.98)	(0.61)	(-1.98)
VW Raw	0.36***	-0.21	-0.57**
	(3.01)	(-0.88)	(-2.16)
VW alpha	0.33***	-0.24	-0.57**
	(2.82)	(-1.04)	(-2.20)
Panel B: Characteristics			
MAX5	3.280	5.386	2.106
LHR	-0.102	0.141	0.243
BETA	1.051	0.948	-0.103
IVOL	2.281	2.749	0.468
LnMV	8.353	8.320	-0.033
LnPB	0.273	0.436	0.163
LnTU	2.736	2.948	0.212
ILLQ	1.575	1.280	-0.295
BASK	0.008	0.007	-0.001
PR01	-0.141	0.176	0.317
PR12	0.182	0.151	-0.031

Table 4

Cross-Sectional Regressions of Stock Returns

This table reports the estimated coefficients of the Fama-MacBeth regressions of monthly return of all firms on the modified MAX (*LHR*), Bali's MAX (*MAX5*) and controlling variables from January 1990 to December 2016. For each month, we cross-sectionally regress returns on independent variables by OLS. The time-series averages are calculated from the cross-sectional estimates of these firm characteristics. Average parameter values are the time series averages, and *t*-statistics are the time-series averages divided by the time-series standard errors. Newey-West *t*-statistics with 12 lags are shown in parentheses. The asterisks *, **, and *** indicate significance at the 10, 5, and 1 levels, respectively.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
	All periods	All periods	All periods	All periods	All periods	Jan. only	No Jan.
Intercept	0.802	0.954**	2.376**	2.314**	2.416**	1.477	2.352*
	(1.45)	(2.30)	(2.00)	(2.03)	(2.08)	(1.25)	(1.87)
LHR	-4.362***		-5.823***		-5.589***	2.515	-6.595***
	(-3.17)		(-4.78)		(-4.11)	(0.45)	(-4.04)
MAX5		-0.098		-0.048	0.012	-0.176	-0.001
		(-1.09)		(-0.45)	(0.10)	(-0.72)	(-0.01)
IVOL			-0.302***	-0.414**	-0.393**	0.539	-0.471***
			(-3.45)	(-2.49)	(-2.38)	(1.07)	(-2.97)
BETA			0.207	0.300*	0.289*	0.495	0.277*
			(1.37)	(1.84)	(1.75)	(1.38)	(1.75)
ILLQ			0.134	0.139	0.148	0.256	0.146
			(1.45)	(1.45)	(1.47)	(1.41)	(1.54)
BASK			24.622	25.736	21.735	91.350	13.644
			(1.22)	(1.37)	(1.08)	(1.31)	(0.56)
LnTU			-0.272***	-0.252***	-0.284***	0.044	-0.318***
			(-2.87)	(-2.76)	(-3.03)	(0.23)	(-3.23)
LnPB			-0.249	-0.250	-0.249	-1.735*	-0.254
			(-1.08)	(-1.12)	(-1.11)	(-1.74)	(-1.21)
LnMV			-0.112	-0.098	-0.116	-0.149	-0.122
			(-1.06)	(-0.95)	(-1.10)	(-1.44)	(-1.10)
PR01			2.477***	0.701	1.690*	-3.977	2.246**
			(3.13)	(0.78)	(1.77)	(-0.87)	(2.28)
PR12			0.812***	0.811***	0.809***	-0.177	0.870***
			(3.40)	(3.33)	(3.40)	(-0.29)	(3.34)
Adj. RSQ	0.011***	0.017***	0.110***	0.109***	0.112***	0.151***	0.110***
	(6.15)	(8.50)	(12.53)	(12.15)	(12.62)	(4.13)	(12.86)

Table 5

Sub-Period Tests

This table reports the estimated coefficients of the Fama-MacBeth regressions in different sub-periods. We define month *t* as expansion (recession) if the value of business cycle indicator in month *t* is greater (lower) than 22 points. The up (down) market months are defined as the periods where market returns are positive (negative). The month *t* is defined as high (low) sentiment if the score of consumer confidence is higher than 75 points. 22 points and 75 points are the median values of business cycle indicator and consumer confidence index over the period from January 2001 to December 2016. The asterisks *, **, and *** indicate significance at the 10, 5, and 1 levels, respectively.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
	Before 2000	2000~2009	After 2009	Up mkt	Down mkt	Expansion	Recession	High Senti	Low Senti
Intercept	-1.389	3.210**	2.036**	4.645***	-0.657	1.039	2.014**	1.762*	3.388*
	(-0.38)	(2.13)	(2.14)	(3.16)	(-0.63)	(0.77)	(2.36)	(1.72)	(1.91)
LHR	-2.866	-3.188*	-10.282***	-6.655***	-5.066***	-7.935***	-5.899***	-7.892***	-5.317***
	(-1.07)	(-1.73)	(-5.56)	(-3.04)	(-2.87)	(-3.74)	(-3.11)	(-3.93)	(-4.00)
MAX5	-0.102	0.166	-0.068	0.379**	-0.379***	0.266	-0.081	0.018	0.353*
	(-0.52)	(0.94)	(-0.37)	(2.32)	(-3.19)	(1.22)	(-0.38)	(0.10)	(1.83)
IVOL	-0.240	-0.632**	-0.241	-0.412	-0.283	-0.637***	-0.519	-0.205	-0.612**
	(-1.28)	(-2.22)	(-0.97)	(-1.44)	(-1.65)	(-2.81)	(-1.46)	(-0.84)	(-2.11)
BETA	0.970***	0.087	0.164	0.784***	-0.115	-0.032	0.255	0.204	0.110
	(4.86)	(0.27)	(1.55)	(3.54)	(-0.65)	(-0.14)	(0.81)	(1.44)	(0.25)
ILLQ	0.709*	0.041	0.023	0.023	0.239*	0.203***	0.021	0.001	0.084*
	(1.73)	(1.24)	(0.22)	(0.17)	(1.85)	(2.92)	(0.35)	(0.02)	(1.84)
BASK	62.440*	-10.888	46.756	65.907**	-17.220	11.199	30.604	41.084	-29.107
	(1.85)	(-0.39)	(1.22)	(2.21)	(-0.51)	(0.38)	(0.74)	(1.29)	(-0.98)
LnTU	-0.366	-0.226*	-0.254***	0.135	-0.771***	-0.285***	-0.047	-0.336**	-0.036
	(-1.48)	(-1.69)	(-2.87)	(0.95)	(-8.36)	(-3.29)	(-0.55)	(-2.60)	(-0.25)
LnPB	-0.459	-0.450	-0.104	-0.584	0.126	-0.629***	0.153	-0.334	-0.280
	(-0.97)	(-1.18)	(-0.54)	(-1.48)	(0.54)	(-2.75)	(0.98)	(-0.78)	(-0.81)
LnMV	0.197	-0.208	-0.118	-0.171	-0.037	0.066	-0.194**	-0.091	-0.304*
	(0.64)	(-1.39)	(-1.25)	(-1.21)	(-0.38)	(0.49)	(-2.37)	(-0.93)	(-1.79)
PR01	1.195	-0.390	5.438***	-1.650	5.680***	1.984	2.562	4.831***	-0.788
	(0.77)	(-0.38)	(3.22)	(-1.19)	(4.85)	(0.99)	(1.00)	(3.22)	(-0.63)
PR12	0.765	0.696**	0.858***	0.230	1.186***	0.746**	0.803	1.088***	0.253
	(1.12)	(2.08)	(3.65)	(0.47)	(3.04)	(2.31)	(1.44)	(4.43)	(0.56)
Adj. RSQ	0.154***	0.125***	0.075***	0.104***	0.119***	0.089***	0.105***	0.082***	0.119***
	(10.69)	(11.82)	(8.26)	(7.60)	(12.79)	(9.16)	(10.12)	(6.53)	(12.40)

Table 6

Modified MAX Premium Conditional on Different Measures of Limits-to-Arbitrage

We form two-dimensional sequentially-sorted portfolios based on stock characteristics and *LHR*. First, we separate stocks into three groups by a given measure of stocks' characteristics. Second, within each characteristics group, we further divide stocks into high and low groups by *LHR*. The highest modified MAX portfolio contains stocks in Groups 10 and 9, and the lowest modified MAX portfolio includes the rest of stocks. The detailed definitions of three limits-to-arbitrage measures are shown in Appendix A.

Panel A: Grouped by Small/Mid/Large Market Capitalization

	Small			*Medium*			*Large*		
	Lowest	*Highest*	*H-L*	*Lowest*	*Highest*	*H-L*	*Lowest*	*Highest*	*H-L*
EW Raw	1.91**	0.50	-1.41***	0.05	0.35	0.30	0.24	0.36	0.12
	(2.43)	(0.84)	(-2.75)	(0.11)	(0.52)	(0.19)	(0.36)	(0.52)	(0.53)
EW alpha	1.76**	0.47	-1.29***	0.00	0.37	0.36	0.23	0.29	0.03
	(2.29)	(0.73)	(-2.71)	(0.10)	(0.53)	(0.20)	(0.35)	(0.51)	(0.51)
VW Raw	1.29**	-0.12	-1.41***	-0.29	-0.21	-0.09	0.06	-0.29	-0.35
	(2.47)	(-0.35)	(-3.10)	(-0.51)	(-0.84)	(-0.37)	(0.19)	(-0.81)	(-1.04)
VW alpha	1.17**	-0.28	-1.45***	-0.25	-0.28	-0.03	0.06	-0.22	-0.28
	(2.32)	(-0.56)	(-3.08)	(-0.52)	(-0.83)	(-0.36)	(0.16)	(-0.82)	(-1.02)

Panel B: Grouped by High/Mid/Low Illiquidity

	Low			*Medium*			*High*		
	Lowest	*Highest*	*H-L*	*Lowest*	*Highest*	*H-L*	*Lowest*	*Highest*	*H-L*
EW Raw	-0.28	-0.35	-0.07	1.34*	0.27	-1.07**	2.42***	0.60	-1.82***
	(-0.39)	(-0.54)	(0.00)	(1.73)	(0.44)	(-2.54)	(2.93)	(0.97)	(-2.85)
EW alpha	-0.24	-0.35	-0.11	1.39*	0.33	-1.06**	2.18***	0.57	-1.61***
	(-0.35)	(-0.55)	(-0.06)	(1.79)	(0.53)	(-2.48)	(2.82)	(0.95)	(-2.63)
VW Raw	-0.50	-0.80**	-0.30	1.20**	-0.32	-1.52***	1.74***	-0.13	-1.87***
	(-1.12)	(-2.38)	(-0.66)	(2.23)	(-0.92)	(-2.96)	(2.87)	(-0.40)	(-3.18)
VW alpha	-0.46	-0.80**	-0.34	1.26**	-0.26	-1.52***	1.52***	-0.14	-1.66***
	(-1.05)	(-2.40)	(-0.71)	(2.30)	(-0.76)	(-2.90)	(2.73)	(-0.45)	(-2.99)

Panel C: Grouped by High/Mid/Low Idiosyncratic Volatility

	Low			*Medium*			*High*		
	Lowest	*Highest*	*H-L*	*Lowest*	*Highest*	*H-L*	*Lowest*	*Highest*	*H-L*
EW Raw	-0.37	1.80*	2.17	0.48	0.88	0.40	1.34*	0.17	-1.17**
	(-0.45)	(1.75)	(1.37)	(0.66)	(1.54)	(0.11)	(1.95)	(0.26)	(-2.20)
EW alpha	-0.34	1.59	1.93	0.48	0.82	0.34	1.08	0.15	-0.93*
	(-0.41)	(1.56)	(1.09)	(0.65)	(1.44)	(0.00)	(1.62)	(0.23)	(-1.83)
VW Raw	0.02	1.01	0.99	0.34	0.05	-0.29	0.80*	-0.38	-1.18***
	(0.04)	(1.15)	(1.05)	(0.80)	(0.18)	(-0.40)	(1.85)	(-1.02)	(-2.59)
VW alpha	0.03	0.82	0.79	0.34	0.01	-0.33	0.57	-0.40	-0.97**
	(0.07)	(0.95)	(0.75)	(0.80)	(0.03)	(-0.53)	(1.38)	(-1.08)	(-2.25)

Table 7

Relations between Modified MAX Premium and Size, Illiquidity, and Idiosyncratic Volatility Premiums

Panel A presents the coefficients of time series regression of modified MAX's (*LHR*) premium on market capitalization (*MV*) premium, Amihud illiquidity (*ILLQ*) premium, and idiosyncratic volatility (*IVOL*) premium, separately or together. Panel B use modified MAX's (*LHR*) premium as an explanatory variable, the rest of premiums are taken as dependent variable. We use the following procedure to make the sign of each premium the same, i.e., positive premium. The *ILLQ* premium is constructed by long buying the highest *ILLQ* and short selling the lowest *ILLQ* portfolio. The rest of premiums use long buying lowest portfolio and short selling the highest portfolio. Except for the modified MAX (*LHR*), we sort all stocks into ten groups based on each variable, separately. The Group 1 (10) is defined as the lowest (highest) portfolio.

Panel A: Modified MAX Premium as Dependent Variable

	Intercept	*MV premium*	*IVOL premium*	*ILLQ premium*	*Adj. RSQ*
Model 1	0.490**	-0.025			0.001
	(1.97)	(-0.81)			
Model 2	0.323*		0.445***		0.350
	(1.71)		(12.53)		
Model 3	0.307*			0.111**	0.018
	(1.73)			(2.52)	
Model 4	0.358*	0.136***	0.526***	-0.124**	0.373
	(1.75)	(3.53)	(12.25)	(-2.30)	

Panel B: Modified MAX Premium as Independent Variable

	Intercept	*MV premium*	*IVOL premium*	*ILLQ premium*	*Adj. RSQ*
Model 1	0.917*	-0.090			0.001
	(1.81)	(-0.81)			
Model 2	-0.045		0.791***		0.350
	(-0.16)		(12.53)		
Model 3	1.365***			0.194**	0.018
	(3.88)			(2.52)	

Table 8

MAX and Idiosyncratic Volatility

We form two-dimensional sequentially-sorted portfolios based on the modified MAX (*LHR*) and then idiosyncratic volatility (*IVOL*). First, we separate stocks into three groups by a given measure of stocks' modified MAX (*LHR*). Second, within each modified MAX (*LHR*) group, we further divide stocks into ten groups by idiosyncratic volatility (*IVOL*). The high portfolio is the Group 10; the low portfolio is the Group 1. The detailed definitions of modified MAX (*LHR*) and idiosyncratic volatility (*IVOL*) are shown in Appendix A.

	Lowest Modified MAX			Highest Modified MAX			
	Low IVOL	*High IVOL*	*H-L* (1)	*Low IVOL*	*High IVOL*	*H-L* (2)	(2) − (1)
EW Raw	0.73**	0.65	-0.08	1.16**	0.30	-0.86*	-0.76*
	(2.05)	(1.15)	(-0.25)	(2.39)	(0.43)	(-1.74)	(-1.70)
EW alpha	0.72**	0.54	-0.17	1.05**	0.15	-0.89*	-0.72*
	(2.01)	(0.97)	(-0.51)	(2.22)	(0.22)	(-1.85)	(-1. 71)
VW Raw	0.24	0.09	-0.15	0.55**	-0.37	-1.16**	-1.01*
	(1.63)	(0.40)	(-1.42)	(2.00)	(-0.91)	(-2.50)	(-1. 71)
VW alpha	0.23	0.01	-0.22	0.45*	-0.50	-1.18***	-0.96*
	(1.58)	(0.05)	(-1.57)	(1.73)	(-1.24)	(-2.65)	(-1. 72)