Economics Bulletin

Volume 40, Issue 1

Investor Attention, Lottery Stocks and the Cross-Section of Expected Returns.

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Abstract

Motivated by previous studies on limited investor attention, preferences for lottery-type assets and poor diversification of many investors' portfolios, we examine the impact of extreme positive stock returns and their relation to expected returns. We find a consistently negative relationship between maximum daily stock returns over the past one month (MAX) and expected stock returns for three broad equity markets, namely the United States, Europe and Japan. This finding generally confirms (but is weaker than) earlier evidence by Bali, Cakici and Whitelaw (2011). As we use a more recent and a broader sample of firms, our study serves as a robustness check of their analysis. Our results cast some doubt, however, on the explanation that this expected return pattern is simply due to high demand for stocks with lottery-type payoffs by certain investors. Instead our findings are more consistent with limited investor attention which affects expected returns of stocks with extreme returns (positive or negative) more generally. Moreover, as opposed to Bali, Cakici and Whitelaw (2011), we find no evidence that controlling for MAX resolves the puzzling negative relationship between idiosyncratic volatility and returns reported in Ang, Hodrick, Xing and Zhang (2006, 2009).

Citation: Maxim Zagonov and Bernd Hanke, (2020) "Investor Attention, Lottery Stocks and the Cross-Section of Expected Returns.", *Economics Bulletin*, Volume 40, Issue 1, pages 18-34
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Submitted: September 24, 2019. **Published:** January 01, 2020.

1. Introduction

Recent empirical evidence suggests that investors are generally not well diversified (see, for example, Odean 1999, Mitton and Vorkink 2007, and Goetzmann and Kumar 2008). Therefore, the distribution of individual stock returns rather than just stocks' co-moments with systematic factors should affect stocks' expected returns.

There is also evidence that investors have limited attention.[1] Therefore, investors tend to be attracted to stocks that are able to catch their attention in some manner. For example, Barber and Odean (2008) find that stocks that have had recent high returns catch the attention of investors who therefore buy those stocks.

Moreover, certain types of investors (particularly retail investors) have been found to exhibit a preference for lottery-type assets, namely those assets that have a small probability of a large payoff which is also related to positive skewness (see, for example, Thaler and Ziemba 1988, Garrett and Zobel 1999, and Walker and Young 2001).

These observations about investor behavior and investor preferences provide the motivation for examining the impact of extreme positive stock returns on expected returns. To address this question, we follow Bali, Cakici and Whitelaw (2011) (henceforth abbreviated as BCW) and sort stocks by their maximum daily returns over the preceding month (MAX), form MAX-based decile portfolios, and examine their monthly returns from January 1992 through January 2017 in the United States, Europe, and Japan. We find that annualized return differences between high MAX and low MAX portfolios vary between -1.68% and -14.71% across regions and across value-weighted and equal-weighted portfolios. The negative relationship between maximum daily returns and expected returns is consistent across all regions but weaker than the results reported in BCW. The return differences that we find tend to be mostly either statistically insignificant or of only borderline statistical significance at the 10% significance level.[2] Nevertheless, these findings suggest that investors are willing to pay more for stocks with extreme positive returns in the past and, as a result, these stocks have lower future returns.[3]

We confirm BCW's findings that stocks with extreme positive returns tend to be small, low-price, high-beta stocks as well as stocks with high idiosyncratic risk and low returns over the past 11 months. We also find that the negative relationship between MAX and returns is robust to controlling for other stock characteristics, namely market beta, size, book-to-market ratio, momentum, reversal, idiosyncratic risk, extreme negative returns and several proxies for return skewness. The robustness is confirmed using bivariate sorts as well as multivariate cross-sectional Fama-MacBeth (1973) regressions.

Of particular interest is the relationship between MAX and idiosyncratic volatility (IVOL) as well as the relationship between MAX and the minimum daily return over the past one month (MIN). We measure IVOL using the methodology of Ang, Hodrick, Xing and Zhang (2006) which is detailed in the appendix. We find that MAX is highly positively correlated with IVOL, as expected. Ang, Hodrick, Xing and Zhang (2006) find a puzzling negative relationship between idiosyncratic volatility and returns despite the fact that one would expect a positive relationship assuming that investors are risk averse and generally hold portfolios that are not well diversified. BCW find that this puzzle is resolved when examining

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[1] See, for example, Kahnemann (1973), Hong and Stein (1999), Hirshleifer and Teoh (2003), Barber and Odean (2008), Cohen and Frazzini (2008).

[2] Moreover, in light of the findings by Harvey, Liu and Zhu (2015) the robustness of the results can be questioned.

[3] In unreported results we confirm that despite having lower future returns, stocks with extreme positive returns in one month are likely to exhibit the same return pattern in subsequent months. Hence it is not irrational for investors to buy these stocks based on their past month's return pattern and given those investors' preference for this type of payoff pattern.

IVOL while controlling for MAX. In other words, once the authors control for MAX, they observe the expected positive relationship between idiosyncratic volatility and returns. We find the opposite, i.e. even after controlling for MAX the relationship between IVOL and returns generally remains negative as reported in Ang, Hodrick, Xing and Zhang (2006, 2009).

Moreover, we find that sign-flipped extreme negative returns (proxied by MIN) are negatively related to expected returns in the same way as MAX. This contradicts the findings of BCW who find a positive relationship. This finding casts some doubt on their evidence linking the return pattern associated with MAX to high demand for lottery stocks. In contrast, the fact the both MIN and MAX are associated with negative expected returns seems to be more consistent with limited investor attention. Both positive and negative extreme returns increase investor attention, who then buy the stocks experiencing those returns. This, in turn, temporarily pushes up their prices and leads to lower future returns.

The remainder of the paper is organized as follows: Section 2 gives a brief overview of the data and methodology. Section 3 presents and interprets the empirical results, first the univariate and bivariate portfolio sorts (Subsections 3.1 and 3.2 respectively) and then the firm-level cross-sectional regressions (Subsection 3.3). Section 4 concludes.

2. Data and methodology

We use market data from Factset as well as Factset Fundamentals accounting data (which was originally based on Worldscope until 2008) to compute book-to-market ratios. Our sample includes the three largest developed market regions, namely the United States, Developed Europe and Japan.[4] The sample period we use is from January 1992 through January 2017. The beginning of the sample period is largely determined by data availability. The number of firms included in our universe at each year end throughout our sample period is shown in Table A1 in the appendix. All data are in GBP.

We use a total market universe which includes large, mid and small capitalization firms. We apply a liquidity screen based on the S&P Global Broad Market Index (BMI) methodology to ensure that stocks are investible. The S&P Global BMI index covers all publicly listed equities generally available to institutional investors with float-adjusted market values of US$100 million or more. At the annual reconstitution, index constituents are removed if their float adjusted market capitalization falls below US$75 million.

In order to examine how our factor of interest (MAX) impacts the cross-section of expected stock returns, we perform both univariate and bivariate sorts controlling for other common and potentially related factors. We also carry out univariate and multivariate cross-sectional regressions at each month end and aggregate the results over time using the Fama and MacBeth (1973) approach.

3. Empirical results

We first carry out portfolio-level analysis using univariate and bivariate sorts based on MAX and other commonly used factors as well as factors that we expect to be related to MAX. We then run firm-level cross-sectional regressions based on Fama and MacBeth (1973). Both approaches have their pros and cons. The portfolio-level analysis based on sorts is non-parametric in the sense that it does not impose a functional form on the relation between MAX

[4] The list of countries included in Developed Europe and the S&P Global BMI methodology are described in: https://us.spindices.com/documents/methodologies/methodology-sp-global-bmi-sp-ifci-indices.pdf.

and future returns. At the same time, the regression approach avoids discarding information in the cross-section due to aggregation from a firm level to a portfolio level, which is the case with the former approach. Moreover, the regression approach allows controlling for multiple factors simultaneously.

3.1 Univariate portfolio sorts

We carry out univariate sorts on MAX in order to create decile portfolios. Table 1 shows subsequent annualized monthly returns for decile portfolios based on MAX(N) sorts where N corresponds to the average of either 1, 3, or 5 highest daily return(s) over the previous month. Sorts are performed at every month end from January 1992 through January 2017. Annualized returns are shown for each of three regions, namely the United States, Europe and Japan. Portfolio 1 (10) is the portfolio with the lowest (highest) MAX(N) over the past one month. The table reports both value-weighted and equal-weighted annualized returns in percent and the average maximum daily return of stocks (MAX(1)) across all stocks within each decile in the last column. The last two rows in each region panel show annualized return differences and corresponding t-statistics for the "High minus Low" portfolio.

Table 1 shows that there are consistently negative return differences for the “High minus Low” portfolios across regions, across value-weighted and equal-weighted portfolios and across different values of N. Return differences are always larger for equal-weighted portfolios than for value-weighted portfolios. This indicates that the effect is larger among small capitalization stocks, a finding which we investigate in more detail below. Moreover, for the most part, returns are monotonically declining from lower to higher MAX(N) deciles. The return decline is usually strongest within the top-2/top-3 deciles where annualized returns decline by up to 7.80% from one decile to the next.

The annualized return differences (“High minus Low”) range from -1.68% to -14.71%. As opposed to the results reported in BCW, these return differences are generally only of borderline statistical significance (at the 5% significance level) for equal-weighted portfolio and statistically insignificant for value-weighted portfolios. The average maximum daily return (MAX(1)) over the previous month tends to be positively skewed across deciles ranging from 1.34% to 13.80% in the different regions. Raw and risk-adjusted returns generally increase slightly if we measure MAX(N) over more days (N). However, qualitatively, the results are similar across different N. Hence, for simplicity, we report results for MAX(1) only (which we call MAX from now on) in the remainder of the paper.[5]

In order to gain a better understanding of stocks with different values of MAX, we examine characteristics of the same decile portfolios sorted by MAX for each region in Table 2. For each of these characteristics median values are shown for each decile (except for MAX itself for which we compute an average). One advantage of medians as compared to means is that they are less subject to any potential outliers in the data.

The first numerical column in Table 2 shows the average maximum daily return (MAX) for each decile. The next column shows median company size (SIZE) for each decile. Company sizes tend to monotonically decrease across deciles, particularly in the United States and less so in Japan. The highest decile of MAX is generally dominated by small cap stocks. This observation is expected because small companies are generally less diversified and more risky or higher-volatility stocks, which makes extreme returns more likely. Average market capitalizations decrease, mostly monotonically, from 12.2 billion to 2.3 billion in the United

[5] We have also examined measuring MAX(N) over three-month and six-month periods. However, for these versions of MAX(N) the results are qualitatively similar but slightly weaker and are not reported for brevity.

States, from 6.5 billion to 3.1 billion in Europe and from 3.9 billion to 3.1 billion in Japan as we move from decile 1 to decile 10. Accordingly, stock prices decrease similarly across deciles, which is shown in the third numerical column.

Table 1. Annualized returns on decile portfolios sorted by MAX(N)

We form decile portfolio every month end from January 1992 through January 2017 by sorting stocks based on the average of the highest N daily returns (MAX(N); where N = 1, 3, and 5) within the past one month for each of three regions, namely the United States, Europe and Japan. Portfolio 1 (10) is the portfolio with the lowest (highest) MAX(N) over the past one month. The table reports both value-weighted and equal-weighted annualized returns and the average maximum daily return of stocks (MAX(1)) within each decile in the last column. The last two rows in each region panel show annualized return differences and corresponding t-statistics for the "High minus Low" portfolio. All return figures are shown in percentage terms.

UNITED STATES	Value Weighted			Equal Weighted			
	N = 1	N = 3	N = 5	N = 1	N = 3	N = 5	Average MAX(1)
Low MAX(N)	13.73	14.57	14.84	16.21	16.48	16.75	1.95
2	13.79	13.34	13.22	16.23	16.76	16.44	2.68
3	13.59	12.04	12.76	15.60	15.30	15.68	3.24
4	12.15	11.75	11.48	15.35	14.91	15.19	3.78
5	11.34	12.57	12.50	14.70	15.30	15.43	4.38
6	11.52	11.45	10.99	14.06	14.06	14.05	5.07
7	8.97	10.60	10.91	12.93	14.11	13.76	5.93
8	11.38	9.81	10.65	12.90	11.94	12.71	7.11
9	8.76	7.99	7.47	9.80	10.21	9.39	9.01
High MAX(N)	7.27	6.86	7.28	3.64	2.41	2.04	13.80
High minus Low	-6.47	-7.71	-7.57	-12.57	-14.07	-14.71	
t-Statistic	-1.22	-1.21	-1.26	-2.27	-2.31	-2.43	
EUROPE	Value Weighted			Equal Weighted			
	N = 1	N = 3	N = 5	N = 1	N = 3	N = 5	Average MAX(1)
Low MAX(N)	11.98	11.89	12.30	10.30	10.20	10.28	1.34
2	11.46	12.40	13.14	12.72	13.30	12.83	2.10
3	12.26	11.78	10.65	13.68	13.00	13.40	2.62
4	10.82	11.17	12.53	12.85	13.31	13.94	3.09
5	9.70	9.90	9.21	12.71	12.77	12.58	3.56
6	8.23	8.56	8.97	11.02	11.93	11.56	4.08
7	8.81	8.95	8.37	10.40	10.64	10.37	4.70
8	9.70	8.91	8.40	9.82	9.24	10.06	5.52
9	6.86	8.67	9.40	8.50	8.45	8.28	6.79
High MAX(N)	10.29	6.95	5.95	3.83	3.03	2.58	10.00
High minus Low	-1.68	-4.94	-6.36	-6.47	-7.18	-7.71	
t-Statistic	-0.47	-1.03	-1.36	-1.84	-1.92	-2.03	
JAPAN	Value Weighted			Equal Weighted			
	N = 1	N = 3	N = 5	N = 1	N = 3	N = 5	Average MAX(1)
Low MAX(N)	5.66	6.05	6.93	7.47	7.47	7.74	2.02
2	7.69	7.64	7.02	8.45	8.42	8.46	2.74
3	5.47	7.83	7.76	7.90	8.77	8.97	3.26
4	4.03	4.57	5.57	6.89	7.50	7.32	3.73
5	5.77	4.98	4.56	8.20	7.54	7.92	4.20
6	6.71	5.26	6.50	6.58	7.20	7.65	4.73
7	5.48	4.44	2.26	6.09	6.06	6.34	5.35
8	6.58	5.98	6.00	6.78	5.96	5.24	6.18
9	1.83	4.09	2.58	3.67	4.25	3.91	7.46
High MAX(N)	0.41	-1.22	-0.30	1.88	0.71	0.42	10.55
High minus Low	-5.25	-7.26	-7.23	-5.59	-6.76	-7.33	
t-Statistic	-1.26	-1.67	-1.63	-1.52	-1.75	-1.81	

Table 2. Characteristics of decile portfolios sorted by MAX

We form decile portfolios every month end from January 1992 through January 2017 by sorting stocks based on the maximum daily return over the past one month for each of three regions, namely the United States, Europe and Japan. Portfolio 1 (10) is the portfolio with the lowest (highest) maximum daily return over the past one month. The table reports time series averages of median values for each month of various characteristics of the stocks within each decile portfolio. The following characteristics are shown: the maximum daily return (MAX), the market capitalization (SIZE), the stock price (PRICE), stocks' market beta (BETA), the book/market ratio (BM), idiosyncratic volatility (IVOL), the return over the past one month (REV), the cumulative return over the 11 months preceding the past month (MOM).

UNITED STATES	MAX (%)	SIZE (10^6)	PRICE	BETA	BM	IVOL (%)	REV (%)	MOM (%)
Low MAX	1.95	12,202	171.80	0.59	0.4906	0.88	-1.21	12.45
2	2.68	10,610	161.45	0.78	0.4754	1.13	-0.50	11.49
3	3.24	8,657	149.02	0.89	0.4652	1.30	-0.06	11.15
4	3.78	7,151	138.35	0.98	0.4616	1.46	0.37	10.82
5	4.38	6,063	129.44	1.06	0.4557	1.65	0.72	9.62
6	5.07	5,066	119.05	1.16	0.4507	1.87	1.10	8.66
7	5.93	4,236	109.46	1.26	0.4423	2.13	1.53	6.76
8	7.11	3,550	97.56	1.38	0.4316	2.46	2.28	4.12
9	9.01	2,943	85.67	1.56	0.4270	2.98	3.51	-0.82
High MAX	13.80	2,301	69.94	1.78	0.4498	4.21	8.32	-13.51
EUROPE	MAX (%)	SIZE (10^6)	PRICE	BETA	BM	IVOL (%)	REV (%)	MOM (%)
Low MAX	1.34	6,500	85.01	0.27	0.5079	0.72	-2.17	10.52
2	2.10	8,374	95.15	0.46	0.5156	0.99	-1.10	10.62
3	2.62	8,145	92.13	0.57	0.5147	1.16	-0.50	10.26
4	3.09	7,762	88.90	0.65	0.5177	1.30	0.04	10.11
5	3.56	7,190	86.54	0.72	0.5173	1.43	0.60	9.46
6	4.08	6,534	81.67	0.78	0.5248	1.57	1.13	8.83
7	4.70	5,830	77.91	0.85	0.5242	1.72	1.81	8.04
8	5.52	5,170	72.13	0.93	0.5306	1.93	2.44	6.38
9	6.79	4,381	64.66	1.05	0.5488	2.24	3.63	3.14
High MAX	10.00	3,064	48.07	1.17	0.6168	3.10	6.77	-6.16
JAPAN	MAX (%)	SIZE (10^6)	PRICE	BETA	BM	IVOL (%)	REV (%)	MOM (%)
Low MAX	2.02	3,930	54.60	0.39	0.8311	1.07	-2.41	1.94
2	2.74	4,604	51.88	0.57	0.8480	1.35	-1.83	2.64
3	3.26	4,768	51.16	0.67	0.8423	1.50	-1.31	2.52
4	3.73	4,697	50.33	0.75	0.8292	1.63	-0.79	2.72
5	4.20	4,653	50.30	0.81	0.8191	1.76	-0.37	2.64
6	4.73	4,557	49.69	0.90	0.8003	1.90	0.22	2.72
7	5.35	4,332	49.52	0.96	0.7808	2.05	0.73	2.65
8	6.18	4,145	49.55	1.04	0.7625	2.24	1.65	2.85
9	7.46	3,677	50.36	1.12	0.7328	2.54	2.93	2.32
High MAX	10.55	2,811	48.68	1.20	0.6998	3.33	6.22	-1.59

As expected, stocks' market betas (BETA) increase substantially across deciles. Higher MAX deciles exhibit considerably higher market betas as stocks with higher market risk have a higher likelihood of extreme daily returns. Market betas increase from 0.59 to 1.78 in the US, from 0.27 to 1.17 in Europe and from 0.39 to 1.20 in Japan.
Book-to-market ratios (BM) are generally similar across deciles. There seems to be no evidence that MAX displays any value or growth tilt (as measured by BM).

Idiosyncratic volatility (IVOL) increases strongly and monotonically across MAX deciles, a pattern which emanates from decile construction. Daily idiosyncratic volatility increases from 0.88% to 4.21% in the United States, from 0.72% to 3.10% in Europe and from 1.07% to 3.32% in Japan. This pattern indicates a strongly positive relationship between MAX and idiosyncratic volatility, which we examine in more detail below.

One might also expect MAX to be related to a reversal factor (REV) measured by stocks' returns over the previous month. Stocks with low (high) returns over the previous month tend to have high (low) returns in the following month, a similar effect as for MAX. Indeed, we can observe in Table 2 that REV strongly increases with increasing MAX across decile portfolios. Again, this pattern tends to be monotonic across deciles, as one would expect. Low MAX portfolios have negative median previous month returns (REV) and high MAX decile portfolios have strongly positive REV. Values of REV range from -1.21% to 8.32% for the United States, from -2.17% to 6.77% for Europe and from -2.41% to 6.22% for Japan.
The last column of Table 2 shows momentum returns (MOM) measured over 11 months preceding the past month. MOM returns are generally monotonically decreasing across deciles, a finding which is consistent with the fact that higher MAX stocks tend to be smaller firms that have had negative past returns. Median momentum returns across deciles vary from 12.45% to -13.51% for the United States, from 10.52% to -6.16% for Europe and from 1.94% to -1.59 for Japan.

In general, we can conclude from the univariate portfolio sorts that the impact of MAX on subsequent (or expected) stock returns is similar to the results reported in BCW for their longer US sample. However, the results over the past 25 years across the three regions are weaker than they report, even for the United States. Presumably their stronger results are driven by the earlier part of their sample period which this study does not cover.

3.2 Bivariate portfolio sorts

As we have seen in Table 2, firm sizes vary substantially across MAX decile portfolios. In order to examine whether the MAX expected return effect is driven by small capitalization firms only, we carry out bivariate dependent sorts. We first sort firms by their market capitalization and form quintile portfolios based on firm size. After that, within each size quintile we form quintiles by MAX. As a result, within each size quintile, we obtain dispersion in MAX while keeping size relatively constant. The subsequent annualized returns of these double-sorted quintile portfolios (both value-weighted and equal-weighted) are shown in Table 3.[6] Size quintiles are shown along the vertical dimension and MAX quintiles are shown across columns.

Table 3 shows that the results from Table 1 generally carry over to the size controlled portfolios, i.e. returns decrease monotonically across MAX quintiles. This return decrease is particularly pronounced when we proceed from MAX Quintile 4 to Quintile 5. The "High minus Low" return differences are always negative, for all regions and for both value-weighted and equal-weighted portfolios. Moreover, these return differences decrease with increasing firm size. The expected return effect of MAX is considerable stronger in small cap than in large cap, particularly for the United States. Annualized return differences for value-weighted portfolios vary between -3.44% and -19.16%. For equal-weighted portfolios these return differences vary between -3.53% and -20.99%. We can observe that return differences are generally only statistically significant for the smallest two size quintiles.

All findings are consistent across regions. By construction, value-weighted and equal-weighted results are similar, as firm size is controlled for within each size quintile so that value-weighted returns are, in fact, approximately equal weighted.

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[6] Note that we showed decile portfolios in Table 1 and Table 2 for better comparability with previous studies in this area. However, for double-sorted portfolios we use quintiles because there are fewer stocks in our sample in Europe and Japan than in the United States. Therefore, 5x5 sorts resulting in a total of 25 portfolios are preferable to 10x10 sorts resulting in a total of 100 portfolios for smaller numbers of firms. The numbers of firms in our regional universes over time is shown in Table A1 in the appendix.

Table 3. Annualized returns on quintile portfolios sorted by MAX after controlling for SIZE

We form double-sorted value-weighted and equal-weighted quintile portfolios every month end from January 1992 through January 2017 by sorting stocks based on the maximum daily returns (MAX) after controlling for market capitalization (SIZE). We first sort stocks into quintiles using SIZE, then within each SIZE quintile, we sort stocks into quintile portfolios based on the maximum daily returns over the previous month. Quintile 1 (5) contains stocks with the lowest (highest) SIZE/MAX. The last column labeled "High minus Low" shows return differences and corresponding t-statistics in parentheses. All return figures are shown in percentage terms

VALUE WEIGHTED		Low MAX	2	3	4	High MAX	High Minus Low
Low SIZE	US	18.87	17.10	14.22	8.63	-0.29	-19.16 (-3.62)
Low SIZE	Europe	10.21	11.29	9.81	6.42	1.42	-8.79 (-2.64)
Low SIZE	Japan	10.29	9.87	10.44	7.59	4.36	-5.93 (-1.66)
2	US	18.20	15.30	15.39	13.69	8.62	-9.58 (-2.14)
2	Europe	12.97	12.86	14.03	9.51	6.62	-6.35 (-2.34)
2	Japan	8.00	7.75	8.21	6.21	0.69	-7.31 (-2.42)
3	US	17.74	15.47	15.53	11.62	10.23	-7.50 (-1.67)
3	Europe	12.54	14.73	12.47	10.65	7.37	-5.16 (-1.92)
3	Japan	5.85	6.31	6.50	5.40	1.39	-4.46 (-1.54)
4	US	15.72	15.51	13.00	12.67	8.46	-7.26 (-1.55)
4	Europe	13.54	12.93	12.85	9.41	8.96	-4.58 (-1.64)
4	Japan	7.65	8.06	6.57	4.08	3.97	-3.68 (-1.44)
High SIZE	US	13.67	13.06	11.91	10.38	8.90	-4.76 (-1.20)
High SIZE	Europe	12.99	11.23	9.75	8.17	6.98	-6.01 (-1.71)
High SIZE	Japan	6.47	4.74	5.41	5.24	3.03	-3.44 (-1.06)
EQUAL WEIGHTED		Low MAX	2	3	4	High MAX	High Minus Low
Low SIZE	US	18.88	17.44	15.37	9.65	-2.11	-20.99 (-3.72)
Low SIZE	Europe	9.47	11.67	10.00	7.18	-0.19	-9.66 (-2.89)
Low SIZE	Japan	10.52	10.73	11.32	8.12	3.80	-6.71 (-1.77)
2	US	18.16	15.29	15.38	13.87	8.44	-9.72 (-2.16)
2	Europe	12.97	12.87	14.01	9.30	6.39	-6.58 (-2.46)
2	Japan	8.05	7.73	8.05	6.59	0.53	-7.52 (-2.44)
3	US	17.75	15.55	15.31	11.32	10.19	-7.56 (-1.62)
3	Europe	12.61	14.75	12.55	10.62	7.11	-5.50 (-2.02)
3	Japan	5.90	6.33	6.63	5.29	1.40	-4.51 (-1.66)
4	US	15.68	15.48	13.10	12.57	8.11	-7.57 (-1.63)
4	Europe	13.48	12.88	12.84	9.21	8.87	-4.60 (-1.62)
4	Japan	7.48	7.99	6.70	4.29	3.95	-3.53 (-1.34)
High SIZE	US	14.03	14.50	12.82	12.01	10.03	-4.00 (-0.93)
High SIZE	Europe	13.53	12.11	11.25	10.64	8.47	-5.06 (-1.65)
High SIZE	Japan	8.07	5.88	5.72	4.88	3.19	-4.89 (-1.76)

In order to investigate whether the expected return effect of MAX is already captured by other previously discovered systematic factors, we examine its relationship with each of the following variables: market beta (BETA), market capitalization (SIZE), book/market ratio (BM), 11-month momentum preceding the last month (MOM), returns over the last one month or short-term reversal (REV), idiosyncratic volatility (IVOL), the minimum return over the past one month (MIN), total skewness (TSKEW), systematic skewness (SSKEW), and idiosyncratic skewness (ISKEW). The exact computation of these variables follows BCW and is described in the appendix.

Table 4. Time series averages of cross-sectional correlations

The table reports the average across months from January 1992 through January 2017 of the cross-sectional correlations of the following variables: market beta (BETA), market capitalization (SIZE), book/market ratio (BM), 11-month momentum skipping the last month (MOM), returns over the last one month or short-term reversal (REV), idiosyncratic volatility (IVOL), the minimum return over the past one month (MIN), total skewness (TSKEW), systematic skewness (SSKEW), and idiosyncratic skewness (ISKEW). The computation of these variables is described in the appendix. Correlations are reported for each of the three regions: United States, Europe and Japan.

		MAX	BETA	SIZE	BM	MOM	REV	IVOL	MIN	TSKEW	SSKEW
BETA	US	0.21									
	EUROPE	0.20									
	JAPAN	0.17									
SIZE	US	-0.28	0.00								
	EUROPE	-0.16	0.10								
	JAPAN	-0.12	0.05								
BM	US	0.05	-0.02	-0.32							
	EUROPE	0.09	0.01	-0.25							
	JAPAN	-0.07	-0.02	-0.36							
MOM	US	-0.15	0.01	0.22	-0.36						
	EUROPE	-0.14	-0.01	0.18	-0.27						
	JAPAN	-0.04	-0.01	0.18	-0.28						
REV	US	0.27	-0.02	0.08	-0.14	0.04					
	EUROPE	0.31	-0.01	0.07	-0.10	0.06					
	JAPAN	0.33	-0.01	0.07	-0.09	0.00					
IVOL	US	0.81	0.18	-0.37	0.09	-0.17	-0.01				
	EUROPE	0.81	0.17	-0.21	0.13	-0.17	0.03				
	JAPAN	0.81	0.14	-0.15	-0.06	-0.03	0.12				
MIN	US	0.46	0.20	-0.30	0.11	-0.12	-0.37	0.76			
	EUROPE	0.44	0.19	-0.17	0.14	-0.14	-0.35	0.75			
	JAPAN	0.44	0.16	-0.13	-0.02	-0.02	-0.24	0.71			
TSKEW	US	0.11	0.00	-0.01	-0.07	0.22	0.12	0.01	-0.11		
	EUROPE	0.08	-0.02	-0.03	-0.02	0.23	0.12	-0.03	-0.15		
	JAPAN	0.23	0.03	-0.09	-0.05	0.13	0.07	0.16	0.02		
SSKEW	US	-0.03	0.02	0.04	0.01	-0.03	0.00	-0.05	-0.04	0.05	
	EUROPE	-0.03	0.02	0.07	0.01	-0.01	0.00	-0.06	-0.05	0.06	
	JAPAN	-0.08	-0.04	0.05	0.01	0.02	0.02	-0.11	-0.10	0.04	
ISKEW	US	0.10	0.00	0.00	-0.08	0.24	0.12	-0.01	-0.12	0.96	-0.02
	EUROPE	0.07	-0.01	-0.02	-0.03	0.24	0.12	-0.04	-0.15	0.98	-0.02
	JAPAN	0.22	0.03	-0.09	-0.05	0.14	0.08	0.16	0.02	0.97	-0.04

Before proceeding to the analysis, we examine any potential overlap between these variables. Table 4 shows time series averages of cross-sectional correlations between these variables over our entire sample period.

As expected, MAX has the highest positive correlations with REV (around 0.3), MIN (around 0.45) and particularly IVOL (around 0.81). The largest negative correlation is with SIZE. As discussed above, smaller firms tend to have higher MAX exposures, presumably due to their higher total risk and higher idiosyncratic risk. Despite the fact that MAX should be related to positive skewness by construction, correlations between MAX and the three measures of skewness (TSKEW, SSKEW and ISKEW) are generally close to zero. Examining the correlations between the different measures of skewness, we observe that ISKEW is almost perfectly correlated with TSKEW. Furthermore, both TSKEW and ISKEW have approximately zero correlation with SSKEW, as TSKEW is almost entirely driven by ISKEW.

Next we perform bivariate sorts to examine whether MAX is robust to controlling for these additional variables one by one. Hence we sort on each of these variables first and form quintile portfolios based on these sorts. Within each of the resulting quintile portfolios we then sort by MAX and form MAX quintile portfolios. This procedure allows us to examine expected returns due to variation in MAX while controlling for another variable. Therefore, MAX quintile portfolios have high dispersion in MAX but similar exposure to the control variable. An advantage of this approach is that it is non-parametric in the sense that it does not impose a functional form on the relation between MAX and future returns.

Table 5 presents average annualized returns across the five control quintiles to produce quintile portfolios with dispersion in MAX but with similar levels of the control variable. Again, we show results for value-weighted and for equal-weighted portfolios. As a reference, the first numerical column (labeled "No Control") shows average MAX univariate quintile returns (i.e. with no controls for other factors).

The univariate sorts by MAX show annualized return differences between Quintile 5 and Quintile 1 ranging between -3.80% to -5.82% across regions for value-weighted portfolios and between -5.26% and -9.49% for equal weighted portfolios. These return differences tend to be statistically significant at the 10% level for equal-weighted portfolios but insignificant for value-weighted portfolios.

As per Table 4, BETA is positively correlated with MAX and therefore stocks in higher MAX portfolios tend to have higher market betas. Controlling for BETA reduces MAX return differences. However, the corresponding t-statistics generally remain constant or increase as the BETA control reduces market risk.

Controlling for SIZE, with exception of Japan, these return differences generally increase and t-statistics become significant at the 5% level. This general pattern is as expected. As reported in Table 2, firm size tends to decrease with increasing MAX. Hence a portfolio betting on MAX without controlling for size would be a bet against size. Since, on average, the size premium has been positive over time, the bet against size would yield reduced returns. By controlling for size, we avoid a bet against size and we also avoid any risk associated with a size bet.

We observe that controlling for BM does not have a strong impact on MAX. This observation is expected given that BM is almost uncorrelated with MAX cross-sectionally.

Controlling for MOM sometimes increases and sometimes decreases return differences between MAX Quintile 5 and Quintile 1 but, interestingly, t-statistics always increase strongly. This pattern indicates that the main effect of controlling for MOM is to lower risk. As MOM decreases when MAX increases, betting on MAX also involves a MOM bet which can be risky. Neutralizing that bet decreases risk. As MAX is positively correlated with REV, controlling for REV always decreases return differences while t-statistics tend to decrease only slightly.

IVOL has a very high cross-sectional correlation with MAX of about 0.8. As a result, controlling for IVOL markedly decreases return differences. However, since IVOL is also a good proxy for a stock’s total risk, controlling for IVOL reduces the risk of the MAX strategy as well. Hence t-statistics sometimes increase and sometimes decrease.

Controlling for MIN, MAX return differences sometimes decrease and sometimes increase. At the same time, t-statistics generally increase as the risk of the MAX strategy decreases because MIN is a proxy for idiosyncratic risk and, therefore, has high correlation with IVOL. The three skewness variables (TSKEW, SSKEW and ISKEW) tend to lower return differences and t-statistics slightly. However, in line with their low correlations with MAX, they do not notably affect the results.

Table 5. Annualized returns on quintile portfolios sorted by MAX after controlling for other factors

We form double-sorted value-weighted (VW) and equal-weighted (EW) quintile portfolios every month end from January 1992 through January 2017 by sorting stocks based on the maximum daily returns (MAX) after controlling for stocks' market beta (BETA), market capitalization (SIZE), book/market ratio (BM), momentum over the 11 months preceding the past month (MOM), returns over the last one month (REV), idiosyncratic volatility (IVOL), minimum daily return over the previous month (MIN), total skewness (TSKEW), systematic skewness (SSKEW), and idiosyncratic skewness (ISKEW). In each case, we first sort stocks into quintiles using the control variable and then, within each quintile, we sort stocks into quintile portfolios based on MAX. Quintile 1 (5) contains stocks with the lowest (highest) MAX. This table presents average annualized returns across the five control quintiles to produce quintile portfolios with dispersion in MAX but with similar levels of the control variable. "HML MAX" is the difference in average annualized returns between the high MAX and the low MAX portfolios along with the corresponding t-statistics. As a reference, the first numerical column (labeled "No Control") shows average MAX quintile returns without controlling for other factors. All return figures are shown in percentage terms.

UNITED STATES		NO CONTROL	BETA	SIZE	BM	MOM	REV	IVOL	MIN	TSKEW	SSKEW	ISKEW
VW	Low MAX	13.62	13.32	16.84	14.69	15.07	12.86	12.22	13.52	13.60	13.75	13.89
	2	12.93	13.08	15.29	13.92	12.47	12.54	12.14	12.69	12.80	13.39	12.34
	3	11.35	10.37	14.01	12.45	11.03	12.24	11.33	9.80	12.22	11.67	12.04
	4	9.82	10.85	11.40	10.87	8.85	11.42	11.03	11.45	10.55	9.98	10.82
	High MAX	8.34	10.27	7.17	8.16	5.62	8.35	9.94	8.05	8.32	8.97	8.83
	HML MAX	-5.28	-3.05	-9.67	-6.54	-9.45	-4.50	-2.29	-5.48	-5.28	-4.78	-5.06
	t-Statistic	-1.17	-0.95	-2.27	-1.77	-3.11	-1.13	-1.22	-1.91	-1.25	-1.26	-1.13
		NO CONTROL	BETA	SIZE	BM	MOM	REV	IVOL	MIN	TSKEW	SSKEW	ISKEW
EW	Low MAX	16.22	16.02	16.90	16.44	17.23	15.12	15.72	16.47	16.21	16.04	16.42
	2	15.48	15.55	15.65	15.97	15.98	14.69	14.41	16.01	15.33	15.53	15.35
	3	14.38	13.24	14.40	15.13	13.71	14.60	13.51	13.29	14.34	13.78	14.21
	4	12.92	12.19	11.88	13.10	11.68	13.75	12.46	11.78	12.71	12.97	12.63
	High MAX	6.73	9.09	6.93	7.62	7.89	7.98	9.81	8.08	7.29	7.66	7.32
	HML MAX	-9.49	-6.93	-9.97	-8.82	-9.34	-7.14	-5.92	-8.39	-8.92	-8.39	-9.10
	t-Statistic	-1.92	-1.91	-2.26	-2.27	-3.14	-1.80	-4.10	-3.33	-1.92	-2.09	-1.94
EUROPE		NO CONTROL	BETA	SIZE	BM	MOM	REV	IVOL	MIN	TSKEW	SSKEW	ISKEW
VW	Low MAX	11.89	12.24	12.45	12.13	11.70	11.46	10.74	10.91	11.57	11.78	11.85
	2	11.56	11.51	12.61	13.12	11.48	10.91	9.35	11.14	12.12	11.26	11.87
	3	9.15	9.29	11.78	10.40	9.68	10.34	10.82	9.44	9.97	10.38	9.98
	4	9.24	7.82	8.83	9.70	8.36	10.05	9.59	9.04	8.86	9.07	9.20
	High MAX	8.10	9.53	6.27	9.59	7.87	8.69	9.27	8.32	9.19	9.30	9.06
	HML MAX	-3.80	-2.71	-6.17	-2.54	-3.82	-2.77	-1.47	-2.59	-2.37	-2.48	-2.79
	t-Statistic	-1.10	-1.21	-2.32	-0.99	-1.83	-0.92	-0.97	-1.15	-0.74	-0.83	-0.83
		NO CONTROL	BETA	SIZE	BM	MOM	REV	IVOL	MIN	TSKEW	SSKEW	ISKEW
EW	Low MAX	11.51	12.17	12.41	11.51	11.91	10.93	10.78	11.44	11.67	11.47	11.82
	2	13.27	12.63	12.86	13.45	12.62	12.65	10.95	12.80	13.01	13.10	12.90
	3	11.86	11.05	12.13	11.17	11.57	12.54	10.81	11.11	12.25	11.67	12.11
	4	10.11	10.31	9.39	10.79	9.58	10.41	10.48	9.65	9.76	10.05	10.02
	High MAX	6.14	6.93	6.13	6.49	7.46	6.71	9.96	7.93	6.44	6.77	6.32
	HML MAX	-5.37	-5.24	-6.28	-5.03	-4.45	-4.22	-0.82	-3.51	-5.24	-4.70	-5.50
	t-Statistic	-1.92	-2.74	-2.35	-2.16	-2.57	-1.78	-0.80	-2.15	-1.94	-1.90	-2.03
JAPAN		NO CONTROL	BETA	SIZE	BM	MOM	REV	IVOL	MIN	TSKEW	SSKEW	ISKEW
VW	HML MAX	6.61	6.28	7.65	8.21	7.60	6.36	7.12	7.38	7.15	5.97	6.74
	2	4.58	8.30	7.34	7.80	6.52	7.01	5.62	5.95	6.06	5.74	6.36
	3	6.26	6.01	7.42	8.17	4.43	6.49	4.34	5.64	4.58	6.11	4.61
	4	6.15	4.88	5.70	7.59	4.10	5.45	5.27	5.47	7.27	5.94	6.65
	High MAX	0.78	0.85	2.91	3.80	0.67	2.92	3.15	1.96	2.77	2.46	2.23
	HML MAX	-5.82	-5.44	-4.74	-4.42	-6.93	-3.44	-3.97	-5.42	-4.38	-3.52	-4.50
	t-Statistic	-1.84	-2.13	-1.82	-1.73	-3.12	-1.39	-2.25	-2.27	-1.55	-1.33	-1.64
		NO CONTROL	BETA	SIZE	BM	MOM	REV	IVOL	MIN	TSKEW	SSKEW	ISKEW
EW	Low MAX	7.96	8.30	8.00	7.87	9.23	7.50	8.36	7.38	7.92	7.80	7.96
	2	7.40	7.73	7.72	7.27	7.70	7.56	6.72	5.95	7.51	7.32	7.59
	3	7.38	7.37	7.68	7.02	6.90	7.35	5.84	5.64	6.97	7.32	7.06
	4	6.44	5.52	5.83	6.47	5.44	6.25	6.72	5.47	5.91	6.28	5.75
	High MAX	2.70	3.10	2.74	3.62	3.00	3.41	4.34	1.96	3.82	3.19	3.69
	HML MAX	-5.26	-5.20	-5.26	-4.25	-6.24	-4.09	-4.02	-5.42	-4.09	-4.61	-4.28
	t-Statistic	-1.84	-2.34	-1.90	-1.62	-3.15	-1.63	-3.42	-2.22	-1.56	-1.74	-1.63

Overall, we observe that univariate sorts on MAX into quintile portfolios generally do not result in statistically significant return differences between the high and low MAX portfolios. It appears that this is at least partially the result of implicit bets on or against SIZE and MOM which has return and risk implications. Once we control for SIZE or MOM respectively, return differences between high and low MAX portfolios generally become statistically significant. While IVOL always strongly reduces MAX return differences, its effect on the associated t-statistics differs by region and by how we weight stocks within portfolios.

3.3 Firm-level cross-sectional regressions

We now proceed from portfolio-level sorts to firm-level cross-sectional regressions. As outlined above, the regression approach avoids discarding information in the cross-section due to aggregation from a firm level to a portfolio level. Moreover, it allows controlling for multiple factors simultaneously. We follow the approach of Fama and MacBeth (1973) and run cross-sectional regressions of monthly stock return on one-month lagged independent variables, which are described in the appendix. We run both univariate regressions as well as multivariate regressions using several combinations of variables.

We start out with univariate regressions using each of the 11 variables one by one as regressors. The univariate regression results are shown in Panel A of Table 6. MAX is negatively related to subsequent stock returns and the relationship is statistically significant for all regions. BETA is sometimes positively and sometimes negatively related to subsequent stock returns but the relationship is never statistically significant. This contradicts the CAPM but is consistent with the findings in the previous academic literature. SIZE is insignificant with mixed signs across regions. BM is positive but only statistically significant in Japan. In contrast, MOM is positive and statistically significant, except in Japan. REV is negatively related to subsequent stock returns, as expected, but it is only statistically significant in Japan. The IVOL results are puzzling but consistent with Ang, Hodrick, Xing and Zhang (2006). Stocks with higher idiosyncratic volatility have lower subsequent returns on average, but the relationship is only statistically significant in Europe. In contrast to BCW we find a negative relationship between MIN and subsequent stock returns, just as for MAX. As MIN is sign-flipped (see the appendix), stocks with more negative minimum daily returns over the past month have lower subsequent returns over the following month.[7] The relationship is however only statistically significant in Europe. The skewness variables TSKEW, SSKEW and ISKEW tend to have unreliable relationships with subsequent stock returns, some of them positive, some negative. This finding is consistent with BCW.

In Panel B of Table 6 we show multivariate regression results. We start by combining MAX with each of the other variables one by one and run bivariate regressions in a similar manner as the bivariate quintile sorts we performed in Table 5. We observe that MAX regression slopes sometimes decrease somewhat in absolute value. However, they generally remain statistically significant at the 5% level. Hence MAX's predictive power for subsequent stock returns is not subsumed by these other variables. We note that particularly IVOL and MIN become weaker if MAX is included in the regression. Their regression coefficients decrease in absolute value and their t-statistics generally decrease compared to the univariate regressions. In contrast to BCW we do not find a positive relationship between IVOL and subsequent stock returns once we control for MAX. Instead, our bivariate regression results continue to be consistent with Ang, Hodrick, Xing and Zhang (2006) just as our univariate results, although the strength of the relationship is reduced by including MAX.

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[7] We confirm this result using quintile sorts in Table A2.

Table 6. Firm-level cross-sectional return regressions

Each month from January 1992 through January 2017 we run firm-level cross-sectional regressions of the return in that month on lagged explanatory variables including MAX. We run both univariate and multivariable regressions. All the variables used are described in the appendix. In each row, the table reports the time series averages of the cross-sectional regression slope coefficients and their corresponding t-statistics in parentheses following Fama and MacBeth (1973). Regression results are shown for the United States, Europe and Japan.

Panel A: Univariate Regressions

	MAX	BETA	SIZE	BM	MOM	REV	IVOL	MIN	TSKEW	SSKEW	ISKEW
US	-0.0382 (-2.24)	-0.0153 (-1.32)	0.0004 (0.04)	0.0130 (0.94)	0.0344 (1.97)	-0.0145 (-1.02)	-0.0350 (-1.81)	-0.0272 (-1.58)	-0.0049 (-1.20)	-0.0127 (-1.63)	-0.0038 (-0.97)
EUROPE	-0.0267 (-2.72)	-0.0105 (-1.09)	0.0092 (1.30)	0.0087 (0.89)	0.0523 (4.05)	-0.0005 (-0.06)	-0.0326 (-2.83)	-0.0297 (-2.66)	0.0106 (3.05)	-0.0021 (-0.40)	0.0114 (3.23)
JAPAN	-0.0207 (-1.98)	0.0103 (1.13)	-0.0086 (-0.82)	0.0462 (4.28)	0.0045 (0.32)	-0.0300 (-2.65)	-0.0163 (-1.26)	-0.0052 (-0.43)	-0.0084 (-1.50)	0.0053 (0.70)	-0.0064 (-1.16)

Panel B: Multivariate Regressions

	MAX	BETA	SIZE	BM	MOM	REV	IVOL	MIN	TSKEW	SSKEW	ISKEW
US	-0.0349 (-2.26)	-0.0070 (-0.90)									
EUROPE	-0.0274 (-3.40)	-0.0024 (-0.31)									
JAPAN	-0.0247 (-2.65)	0.0130 (1.69)									
US	-0.0426 (-2.65)		-0.0100 (-1.16)								
EUROPE	-0.0283 (-2.95)		0.0038 (0.58)								
JAPAN	-0.0229 (-2.34)		-0.0110 (-1.13)								
US	-0.0413 (-2.69)			0.0140 (1.17)							
EUROPE	-0.0258 (-2.97)			0.0103 (1.18)							
JAPAN	-0.0197 (-2.10)			0.0425 (4.24)							
US	-0.0403 (-2.97)				0.0289 (1.98)						
EUROPE	-0.0218 (-3.05)				0.0480 (4.07)						
JAPAN	-0.0238 (-2.85)				0.0044 (0.34)						
US	-0.0353 (-2.11)					-0.0132 (-1.00)					
EUROPE	-0.0255 (-2.52)					0.0002 (0.02)					
JAPAN	-0.0218 (-2.00)					-0.0216 (-1.87)					
US	-0.0314 (-3.55)						-0.0090 (-0.47)				
EUROPE	-0.0043 (-0.55)						-0.0288 (-2.22)				
JAPAN	-0.0170 (-2.30)						-0.0031 (-0.20)				
US	-0.0353 (-2.94)							-0.0090 (-0.72)			
EUROPE	-0.0186 (-2.68)							-0.0199 (-2.15)			
JAPAN	-0.0233 (-3.04)							0.0047 (0.47)			
US	-0.0381 (-2.21)								-0.0006 (-0.14)		
EUROPE	-0.0273 (-2.74)								0.0129 (3.52)		
JAPAN	-0.0198 (-1.88)								-0.0043 (-0.85)		

Continued on the next page

Panel B: Multivariate Regressions (cont'd)

	MAX	BETA	SIZE	BM	MOM	REV	IVOL	MIN	TSKEW	SSKEW	ISKEW
US	-0.0373 (-2.23)									-0.0108 (-1.68)	
EUROPE	-0.0264 (-2.71)									-0.0024 (-0.51)	
JAPAN	-0.0195 (-1.97)									0.0035 (0.53)	
US	-0.0381 (-2.21)										0.0001 (0.01)
EUROPE	-0.0271 (-2.74)										0.0132 (3.65)
JAPAN	-0.0201 (-1.92)										-0.0024 (-0.47)
US	-0.0409 (-3.18)	-0.0057 (-0.73)	-0.011 (-1.41)	0.0097 (0.83)							
EUROPE	-0.0268 (-3.96)	-0.0030 (-0.40)	0.0064 (0.99)	0.0107 (1.28)							
JAPAN	-0.0225 (-2.81)	0.0112 (1.55)	0.0051 (0.59)	0.0435 (4.79)							
US	-0.0391 (-3.53)	-0.0090 (-1.26)	-0.0143 (-1.83)	0.0198 (2.14)	0.0345 (2.81)						
EUROPE	-0.0219 (-3.95)	-0.0035 (-0.52)	0.0008 (0.13)	0.0213 (3.12)	0.0520 (5.13)						
JAPAN	-0.0232 (-3.34)	0.0086 (1.34)	0.0014 (0.17)	0.0467 (6.16)	0.0180 (1.66)						
US	-0.0323 (-2.77)	-0.011 (-1.76)	-0.0122 (-1.63)	0.0149 (1.71)	0.0351 (2.99)	-0.0211 (-1.93)					
EUROPE	-0.0166 (-2.78)	-0.0057 (-0.94)	0.0029 (0.49)	0.0196 (3.08)	0.0512 (5.25)	-0.0138 (-1.57)					
JAPAN	-0.0179 (-2.29)	0.0046 (0.80)	0.0069 (0.90)	0.044 (5.92)	0.0169 (1.57)	-0.0330 (-3.31)					
US	-0.0052 (-0.75)	-0.011 (-1.80)	-0.0155 (-2.14)	0.0142 (1.65)	0.0363 (3.17)	-0.0294 (-2.97)	-0.0325 (-2.91)				
EUROPE	0.0108 (1.69)	-0.0054 (-0.90)	0.0013 (0.21)	0.0200 (3.18)	0.0509 (5.31)	-0.0207 (-2.43)	-0.0323 (-4.29)				
JAPAN	-0.0030 (-0.51)	0.0038 (0.68)	0.0061 (0.80)	0.0430 (5.87)	0.0177 (1.68)	-0.0351 (-3.86)	-0.0171 (-1.78)				
US	-0.0142 (-1.51)	-0.008 (-1.35)	-0.0158 (-2.14)	0.0144 (1.66)	0.0356 (3.07)	-0.0374 (-3.52)		-0.0332 (-5.05)			
EUROPE	-0.0011 (-0.20)	-0.0036 (-0.62)	0.0016 (0.27)	0.0200 (3.18)	0.0510 (5.31)	-0.0290 (-3.18)		-0.0291 (-5.74)			
JAPAN	-0.0099 (-1.55)	0.0046 (0.81)	0.0062 (0.82)	0.0429 (5.86)	0.0175 (1.65)	-0.0384 (-4.17)		-0.0142 (-2.72)			
US	-0.0311 (-2.68)	-0.0108 (-1.75)	-0.0128 (-1.71)	0.0146 (1.68)	0.0370 (3.11)	-0.0204 (-1.88)			-0.0079 (-2.47)		
EUROPE	-0.0167 (-2.79)	-0.0053 (-0.88)	0.0026 (0.43)	0.0199 (3.13)	0.0515 (5.16)	-0.0142 (-1.61)			0.0005 (0.17)		
JAPAN	-0.0169 (-2.21)	0.0046 (0.81)	0.0066 (0.86)	0.0435 (5.85)	0.0172 (1.58)	-0.0334 (-3.37)			-0.0033 (-0.87)		
US	-0.0315 (-2.76)	-0.0106 (-1.74)	-0.0117 (-1.58)	0.0143 (1.66)	0.0356 (3.09)	-0.0214 (-1.99)				-0.0056 (-1.10)	
EUROPE	-0.0165 (-2.76)	-0.0058 (-0.98)	0.0031 (0.52)	0.0190 (3.02)	0.0515 (5.31)	-0.0142 (-1.62)				0.0002 (0.03)	
JAPAN	-0.0161 (-2.15)	0.0046 (0.83)	0.0053 (0.70)	0.0425 (5.80)	0.0164 (1.53)	-0.0341 (-3.53)				0.0040 (0.81)	
US	-0.0310 (-2.67)	-0.0109 (-1.76)	-0.0129 (-1.73)	0.0147 (1.69)	0.0372 (3.12)	-0.0204 (-1.87)					-0.0084 (-2.67)
EUROPE	-0.0165 (-2.77)	-0.0053 (-0.87)	0.0026 (0.42)	0.0198 (3.13)	0.0518 (5.19)	-0.0139 (-1.58)					-0.0005 (-0.19)
JAPAN	-0.0172 (-2.25)	0.0048 (0.83)	0.0064 (0.85)	0.0434 (5.84)	0.0171 (1.58)	-0.0334 (-3.36)					-0.0023 (-0.63)

However, as IVOL and MIN are highly correlated with MAX, the regressions suffer from a high degree of multicollinearity which makes the regression results potentially unreliable despite the fact that they remain unbiased. Therefore, we also carry out bivariate sorts into quintile portfolios for these two variables, controlling for MAX. The results of this analysis are shown in Table A2 in the appendix. They generally confirm our regression results shown in Table 6.

In the next few sets of regressions, we include MAX as a regressor along with combinations of other variables. First, we combine MAX with the Fama and French (1993) factors BETA, SIZE and BM. The regression coefficient on MAX and its statistical significance increase in absolute value in all regions, with t-statistics now ranging from -2.81 (Japan) to -3.96 (Europe). MAX t-statistics mostly increase even further in absolute value (now ranging from -3.34 to -3.95) when we add MOM in the regression model along the lines of Carhart (1997). This increase is consistent with our previous bivariate sort results controlling for MOM. Regression coefficients and t-statistics decrease somewhat once REV is added to the Fama-French-Carhart model, but t-statistics remain highly significant ranging from -2.29 to -2.78). This pattern is expected as MAX and REV are positively correlated and hence contain some common information. We proceed by treating the resulting six-factor model as a base case and add the remaining variables (IVOL, MIN, TSKEW, SSKEW and ISKEW) one by one. Both IVOL and MIN are highly positively correlated with MAX and once we add each of them separately to the regression model, MAX becomes statistically insignificant in both cases. The last three sets of results, with TSKEW, SSKEW and ISKEW added to the regression model one by one, confirm our previous finding that the impact of these variables on MAX is very minor and hence MAX remains highly statistically significant across regions.

4. Conclusion

We document a negative relationship between extreme positive stock returns and expected returns. This finding is consistent over the three broad equity markets that we examine, namely the United States, Europe and Japan. We confirm earlier evidence on the US market by BCW but for a geographically broader and more recent sample of firms. However, in general, we find that the relationship we document is both economically and statistically weaker than what BCW report for their longer US sample. Depending on the specification, we find that the negative return relationship is not always statistically significant. Moreover, our findings cast some doubt on BCW's conclusion that the negative return relationship is due to a higher demand for stocks with lottery-like payoffs. This is because we find the same (rather than the opposite) negative return relationship for stocks with extreme negative returns over the previous month (though somewhat weaker than for MAX), which contrasts BCW's findings. This seems to indicate that both extreme high and low returns catch investors' attention and they therefore temporarily push up prices for those stocks, a move which is then reversed in the subsequent month.[8] Moreover, contrary to BCW, we do not find that once we control for MAX, the puzzling negative relationship between idiosyncratic risk (IVOL) and subsequent stock returns is reversed. IVOL retains its negative relationship with subsequent returns after controlling for MAX, although this relationship is generally not statistically significant at conventional significance levels. Hence the idiosyncratic volatility puzzle reported in Ang, Hodrick, Xing and Zhang (2006) remains.

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[8] This finding might provide an interesting avenue for future research, potentially along the lines of Da, Engelberg and Gao (2011) who propose a measure of (retail) investor attention based on search frequency in Google.

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Appendix

Variable Definitions

Following Bali, Cakici and Whitelaw (2011) we define the variables used in this paper as follows:

MAX
The maximum daily return within a calendar month.

MIN
The negative of the minimum daily return within a calendar month.

BETA (MARKET BETA)
Based on Scholes and Williams (1977) and Dimson (1979) we estimate BETA using the contemporaneous market return as well as one lead and one lag in order to take nonsynchronous trading into account:

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

where $R_{i,d}$ is the return on stock i on day d. $R_{m,d}$ is the market return on day d and $r_{f,d}$ is the risk-free rate on day d. The equation above is estimated using daily returns within a month. The market beta of stock i in month t is the computed as

$$\beta_i = \beta_{1,i} + \beta_{2,i} + \beta_{3,i}$$

IVOL (IDIOSYNCHRATIC VOLATILITY)
To estimate the monthly idiosyncratic volatility of an individual stock i, we assume a single-factor return-generating process:

$$R_{i,d} - r_{f,d} = \alpha_i + \beta_i(R_{m,d} - r_{f,d}) + \varepsilon_{i,d}$$

where $\varepsilon_{i,d}$ is the regression residual and corresponds to the idiosyncratic return on day d. The idiosyncratic volatility of stock i in a given month is then defined as the standard deviation of daily residuals within the month.

SIZE
Following the existing literature, firm size is measured by the natural logarithm of the market value of equity at the end of month t-1 for each stock.

BM (BOOK-TO-MARKET)
Following Fama and French (1992), we compute a firm’s book-to-market ratio in month t using the market value of its equity at the end of December of the previous year and the book value of common equity plus balance-sheet deferred taxes for the firm’s latest fiscal year ending in the prior calendar year.

MOM (MOMENTUM)
Following Jegadeesh and Titman (1993), the momentum variable for each stock in month t is defined as the cumulative return on the stock over the previous 11 months starting two months ago, i.e., the cumulative return from month t-12 to month t-2.

REV (SHORT-TERM REVERSAL)

Following Jegadeesh (1990) and Lehmann (1990), the reversal variable for each stock in month t is defined as the return on the stock over the previous month, i.e., the return in month t-1.

TSKEW (TOTAL SKEWNESS)

The total skewness of stock i for month t is computed using daily returns within year t:

$$TSKEW_{i,t} = \frac{1}{D_t}\sum_{d=1}^{D}\left(\frac{R_{i,d}-\mu_i}{\sigma_i}\right)^3$$

where D_t is the number of trading days in year t, $R_{i,d}$ is the return on stock i on day d, μ_i is the mean of returns of stock i in year t, and σ_i is the standard deviation of returns of stock i in year t.

SSKEW and ISKEW (SYSTEMATIC and IDIOSYNCHRATIC SKEWNESS)

Following Harvey and Siddique (2000), we decompose total skewness into idiosyncratic and systematic components by estimating the following regression for each stock:

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

where $R_{i,d}$ is the return on stock i on day d, $R_{m,d}$ is the market return on day d, $r_{f,d}$ is the risk-free rate on day d, and $\varepsilon_{i,d}$ is the idiosyncratic return on day d. The idiosyncratic skewness (ISKEW) of stock i in year t is defined as the skewness of daily residuals $\varepsilon_{i,d}$ in year t. The systematic skewness (SSKEW) or co-skewness of stock i in year t is the estimated slope coefficient γ_i.

Table A1. Numbers of firms over time

This table shows the sample size over time for the three regions (United States, Europe and Japan) at each year end from 1992 through 2016.

	United States	Europe	Japan
1992	1837	1457	1212
1993	2083	1404	1344
1994	2347	1549	1400
1995	2440	1592	1410
1996	3005	1695	1458
1997	3153	1778	1307
1998	3499	1967	971
1999	3312	2062	1008
2000	3296	2272	1167
2001	3024	2004	1168
2002	2925	1840	1109
2003	2881	1739	1083
2004	3243	1917	1335
2005	3453	2113	1629
2006	3371	2213	1701
2007	3318	2324	1580
2008	3012	2059	1397
2009	2715	1709	1292
2010	2760	1791	1260
2011	2810	1813	1303
2012	2770	1627	1301
2013	2958	1691	1417
2014	3070	1870	1554
2015	3070	1928	1628
2016	2954	1928	1658

Table A2. MIN & IVOL: Annualized returns of quintile portfolios

We form quintile portfolios every month end from January 1992 through January 2017 by sorting stocks based on the minimum daily return over the past one month (MIN) and based on their idiosyncratic volatility (IVOL) over the past month respectively. We also perform the same quintile sorts but controlling for MAX: we first sort stocks into quintiles using the control variable MAX and then, within each quintile, we sort stocks into quintile portfolios based on MIN and IVOL respectively. Quintile 1 (5) contains stocks with the lowest (highest) MIN or IVOL. This table presents average annualized returns across the five control quintiles to produce quintile portfolios with dispersion in MIN or IVOL but with similar levels of the control variable MAX. All return figures are shown in percentage terms.

		UNIVARIATE		BIVARIATE (controlling for MAX)	
UNITED STATES		MIN	IVOL	MIN	IVOL
Value Weighted	Low	11.25	12.97	10.70	11.06
	2	13.15	11.90	11.97	10.45
	3	12.12	12.07	11.92	12.29
	4	13.01	12.03	11.77	12.36
	High	7.14	7.56	9.43	11.50
	High Minus Low	-4.11	-5.40	-1.28	0.44
	t-Statistic	-0.91	-1.03	-0.46	0.25
		MIN	IVOL	MIN	IVOL
Equal Weighted	Low	13.42	14.72	12.33	12.41
	2	14.84	15.12	13.31	13.29
	3	15.50	14.57	14.39	14.25
	4	13.92	14.55	13.61	14.53
	High	8.03	7.03	12.09	11.49
	High Minus Low	-5.39	-7.68	-0.24	-0.92
	t-Statistic	-1.12	-1.53	-0.17	-0.35
EUROPE		MIN	IVOL	MIN	IVOL
Value Weighted	Low	10.79	11.64	10.65	10.46
	2	10.49	10.32	9.48	10.20
	3	10.37	9.95	10.26	10.27
	4	8.97	9.07	11.35	10.45
	High	8.27	7.90	8.44	8.86
	High Minus Low	-2.52	-3.74	-2.22	-1.60
	t-Statistic	-0.76	-1.03	-0.83	-0.77
		MIN	IVOL	MIN	IVOL
Equal Weighted	Low	12.00	12.19	12.00	12.03
	2	12.24	12.55	11.24	11.69
	3	12.10	12.52	11.00	10.34
	4	10.86	10.41	10.90	11.06
	High	5.80	5.33	7.82	8.01
	High Minus Low	-6.20	-6.87	-4.17	-4.02
	t-Statistic	-1.90	-2.13	-1.91	-2.03
JAPAN		MIN	IVOL	MIN	IVOL
Value Weighted	Low	6.53	6.35	5.62	6.12
	2	4.59	6.21	4.59	5.28
	3	5.95	5.18	5.07	5.16
	4	4.91	4.72	6.23	4.91
	High	5.64	3.70	5.17	5.49
	High Minus Low	-0.89	-2.65	-0.45	-0.64
	t-Statistic	-0.33	-0.72	-0.26	-0.34
		MIN	IVOL	MIN	IVOL
Equal Weighted	Low	6.00	6.78	5.72	6.22
	2	6.11	7.33	5.90	6.52
	3	6.30	7.33	6.26	6.45
	4	7.75	6.70	6.50	6.19
	High	5.76	3.93	7.56	6.46
	High Minus Low	-0.24	-2.84	1.84	0.24
	t-Statistic	-0.12	-0.85	0.74	0.14