Academic Research Monitor
Recession and Tail Risk

Equities

Global
Quantitative

Forecasting recessions and measuring tail risk
Can we forecast recessions? Is tail risk a priced factor in the cross-section of stock returns? Can we explain the performance of risk premia as compensation for tail risk? We track the latest academic advances and provide insight on these questions.

Recession Forecasting via Bayesian Classification
Constructing a predictive model to forecast a recession is a difficult task, due to the so-called class imbalance (a recession is a rare event). The first paper that we review compares three binary classifiers for predicting recessions in the US and finds that Bayesian classifiers generally provide good signals about the onset of a recession even up to 12 months in advance. Motivated by these findings, we replicate the analysis for the Euro area but find the results less convincing, partly due to the lack of long historical data.

Tail Risk and Stock Returns
We review two recently published papers on how one should define and quantify tail risk. In the first paper, a measure of aggregate market-wide tail risk is constructed using cross-sectional stock returns. This measure is advocated for forecasting market returns, whereas stocks with large exposure to it are shown to outperform the stocks with low exposure to it by about 4.2% per annum (top minus bottom quintile, value-weighted, 1963 - 2010). This measure of tail risk is also shown to be related to future economic activity. A shock to tail risk is related to an immediate contraction over the subsequent year even after controlling for aggregate volatility.

Tail Risk and Risk Premia
The second paper on tail risk introduces a new measure of skewness based on ranked absolute historical returns. Based on this, it is shown that most of the risk premia across various asset classes (equity size, equity momentum, corporate bond premium, FX carry, volatility selling and others) can be partly interpreted as compensation for bearing tail risk. The only exceptions to this finding are equity value, equity low-volatility and trend-following, which are not exposed to (this very specific definition of) tail risk.

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Introduction

Quantifying the concept of risk (and the reward associated with it) has always been a rich field of research in financial economics. In this ARM we look at two aspects of downside risk; recession risk and tail risk; see the papers that we review in Figure 1.

Forecasting recessions

First, we look at a recent paper that focuses on forecasting recessionary periods up to 12 months in advance using a number of economic and financial variables and a novel Markov-Switching Naïve Bayes forecasting model. We evaluate the performance of the model in the US and try to shed some light on the respective dynamics in Europe.

Tail risk and asset pricing

Then, we review two recently published papers that suggest new metrics of tail risk and then investigate the asset pricing implications of tail risk using these metrics. In particular, the first paper looks at whether aggregate tail risk is priced in the cross-section of stocks returns, and whether it can forecast future market returns as well as future economic activity. Instead, the second paper looks at a number of risk premia across various asset classes (equity factors, credit and FX carry) and explores whether the profitability can be explained as compensation for bearing tail risk.

Figure 1: Papers on Recession and Tail risk

"Recession Forecasting Using Bayesian Classification" *Troy Davig and Aaron Smalter Hall*	SSRN working paper, September 2016
"Tail Risk and Asset Prices" *Bryan Kelly and Hao Jiang*	*Review of Financial Studies, Volume 27(10), 2014*
"Risk Premia: Asymmetric Tail Risks and Excess Returns" *Yves Lemperiere, Cyril Deremble, Trung-Tu Nguyen, Philip Seager, Marc Potters and J.-P. Bouchaud*	*Quantitative Finance, Volume 17(1), 2017*

Source: UBS

"Recession Forecasting Using Bayesian Classification"

by Troy Davig, and Aaron Smalter Hall

Is it possible to forecast a recession?

In their recent paper, Troy Davig and Aaron Smalter Hall present and explore the properties of a number of data-driven approaches for forecasting recession periods. Compared to the predictions made by the Survey of Professional Forecasters (SPF), the proposed methods appear to be more successful at predicting business cycle turning points up to 12 months in advance.

Three forecasting models to be tested

The authors look to forecast US recessions, as determined by the NBER (National Bureau of Economic Research), using a large number of predictors and three binary classifiers: Logistic regression with logit link (LR), Naïve-Bayes (NB) and Markov-Switching Naïve Bayes (MS-NB). The latter two models are briefly introduced below.

Naïve-Bayes forecasting model

Given observed data at time t, $\mathbf{x}_t = (x_1, \dots, x_m)$ of m variables (features), the probability of a recession (denoted by R; an expansion is denoted by E) is expressed according to Bayes rule as follows:

Bayes rule

$$P(R_t|\mathbf{x}_t) = \frac{P(R_t)f(\mathbf{x}_t|R_t)}{P(R_t)f(\mathbf{x}_t|R_t) + P(E_t)f(\mathbf{x}_t|E_t)} \propto P(R_t)f(\mathbf{x}_t|R_t) = prior \times likelihood$$

Assuming "naïve" conditional independence among features, given that the economy is in a recession at time t, the posterior $P(R_t|x_t)$ becomes:

$$P(R_t|\mathbf{x}_t) \propto P(R_t) \prod_{i=1}^{m} f(x_{i,t}|R_t)$$

The prior in the NB model is chosen to be the empirical probability of a recession calculated from the training data. For instance, in the period January 1959 through June 2016, the economy was in recession 13.5% of the time. Hence, the prior derived from that training period would be $P(R_t) = 0.135$ and $P(E_t) = 0.865$ for a recession and expansion, respectively.

One drawback of this approach is that it treats forecasts for all periods as independent and therefore disregards the fact that the two states are persistent over time. For the same sample period (Jan. 1959 to June 2016) it was calculated that while in expansion, 98.5% of the time the economy was also in expansion the following month; the corresponding figure for the recessionary state was 91.4%.

Markov-Switching Naïve Bayes forecasting model

To account for this state persistence in terms of future forecasts the authors suggest using an adjusted prior that is sequentially calculated based on the latest estimate of the posterior and the empirical Markov transition probabilities. For example, the prior probability of a recession one month from now becomes:

Incorporating state persistence

$$\begin{aligned} P(R_{t+1}|\mathbf{x}_t) &= P(R_{t+1}|R_t, \mathbf{x}_t) \cdot P(R_t|\mathbf{x}_t) + P(R_{t+1}|E_t, \mathbf{x}_t) \cdot P(E_t|\mathbf{x}_t) \\ &= P(R_{t+1}|R_t) \cdot P(R_t|\mathbf{x}_t) + P(R_{t+1}|E_t) \cdot P(E_t|\mathbf{x}_t), \end{aligned}$$

where the second equation follows from the Markov property assumption of the Markov-switching model.

The data used by the authors to train the models consists of 135 macro variables reported monthly and contained in the FRED-MD[1] dataset. However, most of the

[1] The data was pre-processed according to the methodology by McCracken and Ng (2016).

analysis is performed on a subset of it, containing four variables and their lags of length 1 to 10:

The forecasting variables

- ISM Manufacturing: Production Index (NAPMPI)
- Total non-farm payroll growth (PAYEMS)
- 10-year treasury rate minus Fed funds rate (T10YFFM)
- Returns to the S&P's Common Stock Price Index (S&P500).

The sample period is January 1959 through June 2016. It is worth noting that as of June 2016 the NAPMPI has been discontinued from the FRED-MD dataset.

Real-time forecasting: using a "blind" period of 18 months

To be able to mimic real-time forecasting as closely as possible, the authors introduce a "blind" of 18 months, meaning that the most recent 18 months are excluded from the training set. This is because NBER recessions are determined retroactively – information about the state of the economy at time t would not have been available to estimate the model parameters for that time period.

Model evaluation

The performance of the models is evaluated entirely on an out-of-sample basis using rolling forecasting experiments on an expanding window basis. The initial training period ends in December 1972 and the first test data point to be forecasted is January 1973. The forecast horizons, h, are set to be $\{0, 3, 6, 9, 12\}$ months ahead. In addition, forecasts are constructed to indicate whether a *recession will begin within the next* h number of months as opposed to whether the economy will be in a recession at h number of months in the future.

The issue of class imbalance; forecasting a rare event

Choosing an appropriate measure to evaluate the performance of a classification model is crucial when the classes are highly imbalanced. A trivial classifier, which always forecasts that the economy is in expansion, would have been accurate 86.5% of the time for the sample period under consideration; it is clear, however, that such a model has no predictive power. To address this problem, the authors choose to look at the F-measure instead of prediction accuracy in absolute terms. For completeness, the Mean Absolute Error (MAE) has been also reported.

Timing-dependent error weights

Both F-measure and MAE treat errors equally; however, in a recession forecasting context it is important to consider the timing of errors – a recession forecasted in the middle of an expansion would be considerably worse than predicting a recession a few months prior to when it begins. The authors propose a weighting scheme that penalises prediction errors in the middle of the business cycle more heavily than those near the edge of cycle transitions. Figure 2 defines and summarises the properties of the methods deployed for model evaluation.

Figure 2: Evaluation criteria

	Definition	Notes
Accuracy	$\frac{1}{n}\sum_{i=1}^{n} I[\hat{y}_i = y_i]$	Could be misleading when classes are imbalanced
F-measure	$F = 2 \cdot \frac{precision \cdot recall}{precision + recall}$	Penalises trivial classifiers; does not take into account timing of errors
MAE	$\frac{1}{n}\sum_{i=1}^{n} \lvert P(R\lvert\mathbf{x}_i) - y_i\rvert$	Not appropriate for classification problems
Timing-dependent Error Weights	Forecast errors are multiplied by the corresponding error weight	Penalises errors depending on when they occur.

Source: UBS Quantitative Research. For the F-measure, "precision" is defined as the fraction of positive predictions which are truly positive, and "recall" is defined as the fraction of truly positive observations that were predicted positive. See the actual paper for further details.

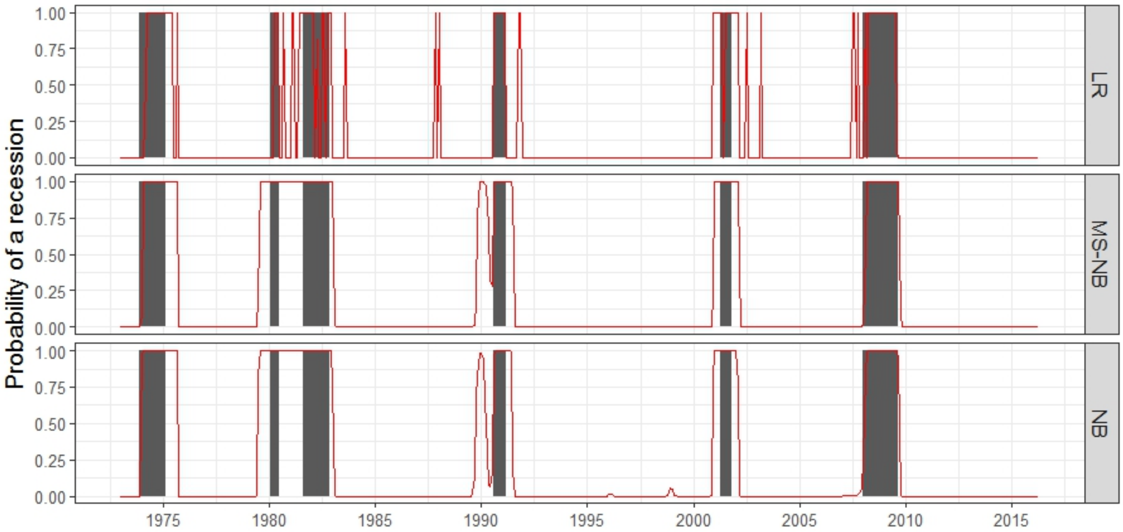
Recession Classification Performance

In addition to the various forecasting models, the authors also evaluate the accuracy of the predictions made by the SPF. The reported results were further divided into four categories, depending on the variable set[2] used for model training and forecasting. Being the most competitive classifier, we focus on the model that uses the core set of four variables with their lags. Comparison was also made across revised and real-time data for the each variable set.

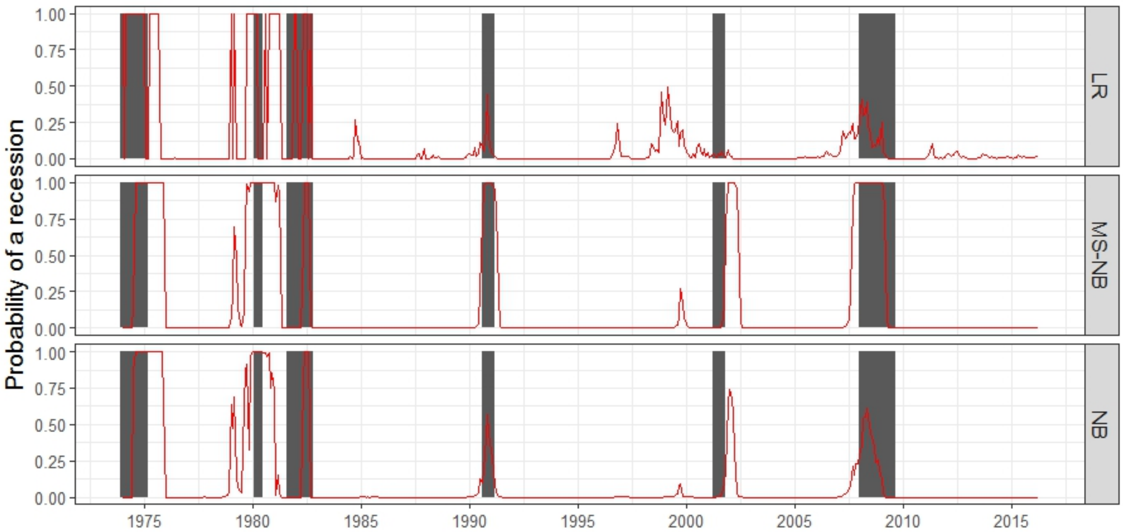
By replicating the methodology, we present in Figure 3 the forecasted recession probabilities for the three models for the current month (Panel A) and for 12 months ahead (Panel B).

Figure 3: Estimated recession probabilities

Panel A: Current month forecasts



Panel B: 12-month ahead forecasts



Source: UBS Quantitative Research, NBER, FRED-MD dataset. The forecasts are generated based on our replication of the analysis in the paper.

[2] The four categories include: i) the core set of four variables and their lags, ii) term spread only, iii) all 135 variables, and iv) Conference Board's Leading Economic Indicator.

The main result reported by the authors, and confirmed by our replication of their analysis, is that the MS-NB model always outperforms the LR model based on the F-measure with timing-dependent errors. For the real-time core set of variables, the gap between the two models is relatively small for current month forecasts, but widens significantly as the forecasting horizon increases. Based on MAE, the results are qualitatively the same. When uniform error-weights are used, LR marginally outperforms only for current month forecasts.

MS-NB appears to be the most successful classifier

These results are in line with Figure 3. In contrast to the LR predictions, one-month ahead forecasts made by MS-NB and NB are much more persistent over time. Therefore, if timing of the errors is not taken into account, LR performs better than the Bayesian classifiers overall, as it has fewer errors. On the other hand, when timing-dependent F-measures are calculated, LR is heavily penalised for giving false signals in the middle of expansions. Finally, it is important to notice that for longer-term horizons (see Panel B of Figure 3) LR fails to pick up all three recessionary periods after 1990.

The reason for the outperformance of MS-NB according to the authors is the fact that NB converges to its asymptotic error rate quicker than LR. Given the limited business cycle data and in particular the number of recessionary periods, this fact proves to be advantageous when making predictions.

Implementing the forecasting models outside the US

Having reproduced the US recession classifiers, we looked into constructing similar predictive models for the Euro area. To this end, we obtained Centre for Economic Policy Research (CEPR) business cycle turning points, which date back to 1970. Due to the lack of consistent macroeconomic data with long enough history, the variables that we used to train the models were (including lags from 1 to 10):

Can we build a recession predictive model for Europe?

- The term spread in Germany (10-year bond yield minus 3-month rate)
- The difference between German and Italian 10-year bond yields.

The first variable captures the slope of the yield curve in Europe and is considered to be the equivalent to the 10-year treasury rate minus Fed funds rate variable that was used in the US analysis. The second variable has no equivalent in the US, and we decided to include it in the analysis in order to capture the differences in sovereign creditworthiness across the European continent, which became severe during the recent Eurozone debt crisis.

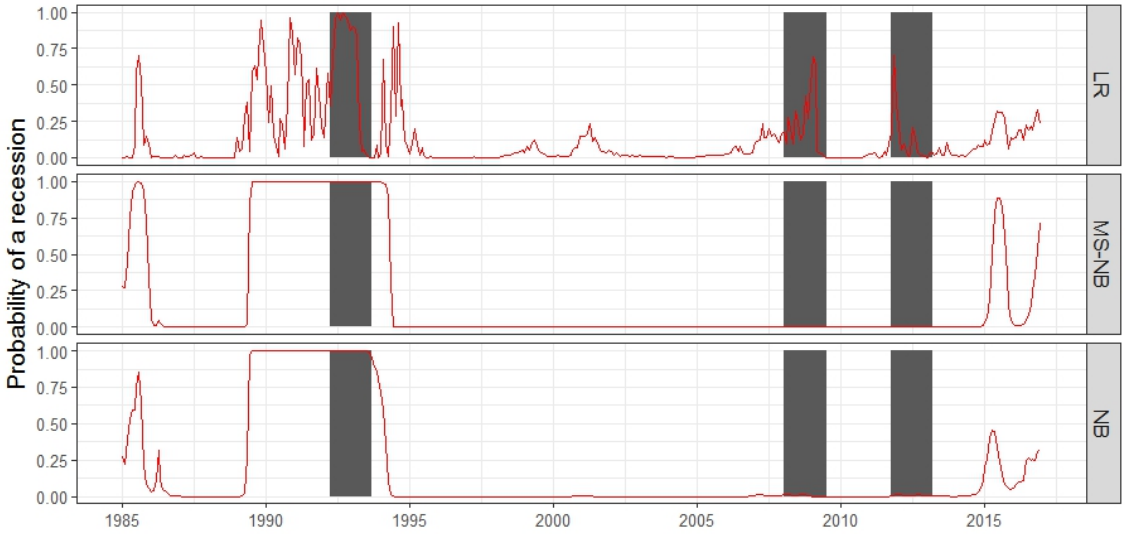
The initial training period for the models ends in December 1984, which was chosen so to include two recessionary periods.

Figure 4 presents the current month recession probabilities estimated by the various models from a rolling forecasting experiment. In order to have a fair comparison with the US results, we re-run the US analysis using only the 10-year treasury rate minus Fed funds rate variable, including lags from 1 to 10 (as opposed to using the four-variable set that was used to generate the results presented earlier in Figure 3); these results are shown in Figure 5.

Broadly speaking, the results for Europe are not as convincing as they are for the US. In contrast to the US, the LR classifier seems to be the only one that has some predictive power for Europe, as it has managed to pick up the latest two recessions and more importantly, the most recent one, associated with the Eurozone debt crisis, which is unique to the Euro area.

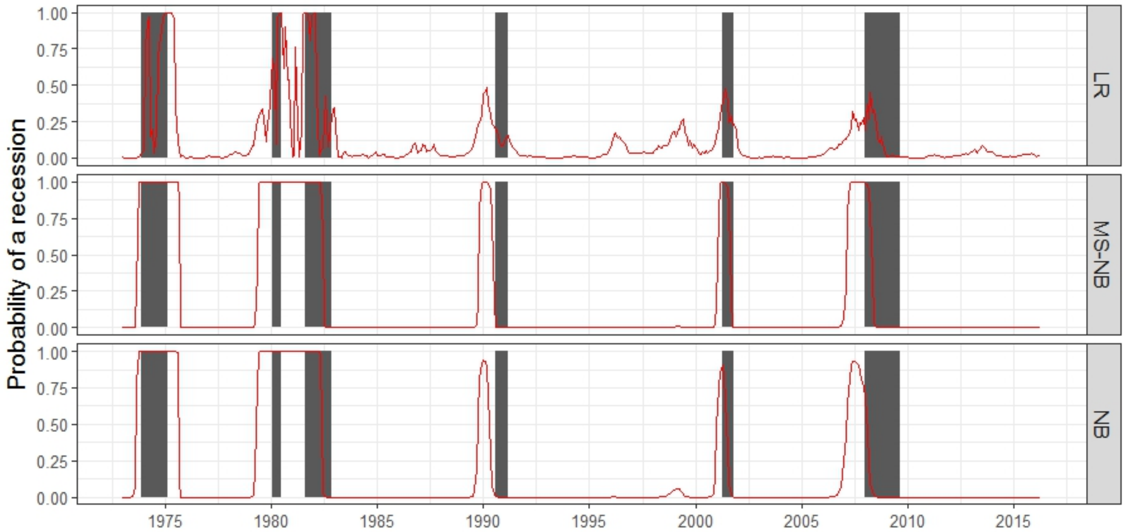
The results for Europe are not as strong as they are for the US

Figure 4: Current month recession predictors for Europe



Source: UBS Quantitative Research, CEPR, Global Financial Data

Figure 5: Current month recession predictors for the US using only the term spread as the predictor variable



Source: UBS Quantitative Research, NBER, FRED-MD dataset

We believe that the reason for underperformance in Europe is twofold. Firstly, the Euro area is much more segmented than the US, especially prior to establishing the single currency. Therefore, in order to capture the dynamics in the region one would have to use a much larger set of predictors. The second problem is precisely the lack of such a wide range of macro variables with have long enough history.

Final word

In summary, the Bayesian classifiers proposed in this paper, and in particular the MS-NB model, provide a good signal about the onset of a recession in the US up to 12 months in advance. However, due to the absence of good quality data in other regions, recession forecasting using a similar methodology remains a challenge.

Measuring Tail Risk

When "risk" is not just volatility

A key axiom underpinning the foundations of quantitative finance is the relationship between risk and return; an investor expects to be compensated for taking on greater amounts of risk. Risk, however, has historically most often been defined by the volatility of returns. There are several reasons why volatility should not be assumed as an ideal risk measure:

- Investors do not perceive changes in wealth symmetrically. Behavioural finance acknowledges greater fear of large losses associated with rare, yet probable events.
- Volatility only captures the first two moments of the return distribution and its use centres on the assumption of symmetrical returns. It therefore fails to capture higher-moment tail risk.

Following the above observations, academics and practitioners have explored several methods for measuring risk that accounts for those rare tail events. In this section, we review some recent literature on measuring tail risk and subsequently on evaluating the asset pricing implications of tail risk on stock returns (first paper) and on a number of risk premia across various asset classes (second paper). Put differently, the first paper investigates whether stocks with that are exposed to a market-wide definition of tail risk outperform, in which case this outperformance can be interpreted as compensation for bearing tail risk. Instead, the second paper looks at a number of heavily studied risk premia across asset classes (like equity value, size, momentum, FX carry and other) and investigates whether they can be interpreted again as compensation for exposure to tail risk.

"Tail Risk and Asset Prices"

by Bryan Kelly and Hao Jiang

Estimating tail risk from the cross-section of stock returns

Whilst investors care about the extreme downside risk of individual holdings, it is a challenge to quantify tail risk from univariate time-series since these extreme events are very rare. Hence, the objective of Bryan Kelly and Hao Jiang in this paper is to investigate the asset pricing implications of a market-wide definition of tail risk on stock returns. Their suggestion is to construct a time-varying measure of tail risk directly from the cross-section of stock returns so to capture common variation in tail behaviour.

Modelling tail behaviour using a power law structure

The authors assume that the form of the distribution of tail events is common across all stocks and follows a power law structure:[3]

$$P\left(R_{i,t+1} < r \middle| R_{i,t+1} < u_t \text{ and } \mathfrak{I}_t\right) = \left(\frac{r}{u_t}\right)^{-a_i/\lambda_t}$$

where $\mathfrak{I}_t$ represents the information available at time t, a_i is a stock-specific characteristic, λ_t is a common, market-wide tail characteristic and u_t is the time t threshold, beyond which we assume to observe a "tail event" (this threshold is set by the authors at the end of each month to the fifth percentile of the pooled daily returns of all stocks over the month). The tail exponent a_i/λ_t represents the shape of the tail; given that $r < u_t < 0$ in the expression above, we get $r/u_t > 1$, and therefore we must have $a_i/\lambda_t > 0$ to ensure that the probability lies between zero and one. Whilst each asset has its own level of tail risk (captured by a_i), the

[3] The same specification has been used by Wu (2016), who focuses on extreme liquidity risk; we have reviewed this paper in our October 2013 ARM.

underlying assumption is that tail risks for all assets share the same dynamics (captured by λ_t). The latter parameter is the parameter of interest, which is estimated using Hill's (1975) power law estimator:

$$\lambda_t^{Hill} = \frac{1}{K_t}\sum_{k=1}^{K_t} \ln \frac{R_{k,t}}{u_t}$$

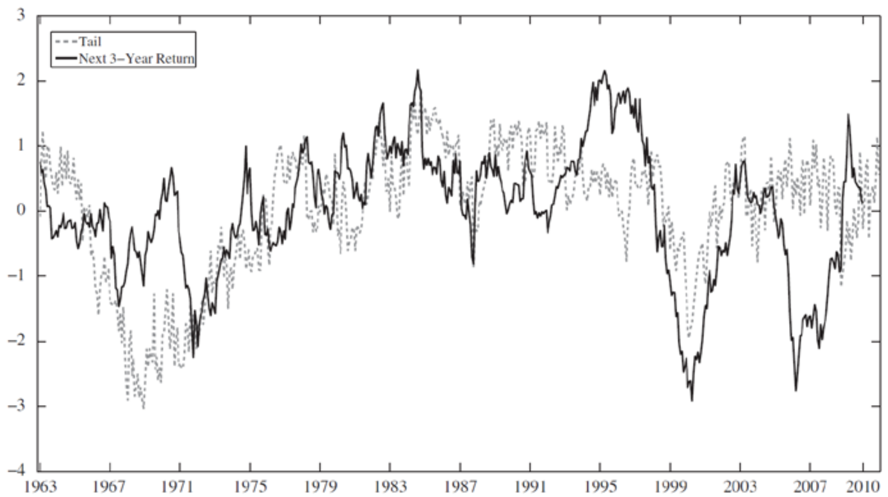
Here, $R_{k,t}$ is the k^{th} daily return that falls below the threshold, u_t, during month t and K_t is the number of times the returns breach that threshold each month.

Market-wide tail risk is persistent

The tail parameter, λ_t, is estimated on a monthly basis and is found to be highly persistent; high values of λ_t signal fat tails and an increased likelihood of an extreme (negative) event. The authors hypothesise, therefore, that tail risk, as specified above, is persistent and one can use the predictive power of λ_t to forecast aggregate stock returns. To further justify the use of their measure, they also document a strong relationship with option implied moments (namely skewness and kurtosis) and fundamentals.

In their empirical analysis, the dynamic power law exponent, λ_t, is computed using monthly observations (pooled from daily returns) from the CRSP database over the period January 1963 to December 2010 for NYSE, AMEX and NASDAQ stocks with the usual selection criteria. Tail estimates are plotted vs. subsequent 3-month returns in Figure 6 (both series are scaled to zero mean and unit variance).

Figure 6: Tail risk exponent estimates and subsequent 3-month market returns



Source: "*Tail Risk and Asset Prices*" by B. Kelly & H. Jian; Figure 1, reproduced with permission.[4] The figure compares the time-series of tail exponent estimates with the subsequent 3-month returns over the period 1963-2010 of stocks from NYSE, AMEX and NASDAQ. Both series are scales to zero mean and unit variance.

Can tail risk forecast future equity market returns?

The authors then look at the ability of their tail risk measure to forecast aggregate market excess returns. They use univariate predictive regressions where the dependent variable is the excess return of a value-weighted index over the following month, year, three years or five years. A large number of other predictor (fundamental and economic-related) variables are used in this analysis (Goyal and Welch, 2008). The results are shown in Figure 7. Note that all coefficients related to predictor variables are scaled so that one can "interpret" the effect that a one-standard-deviation change in a predictor variable has on future market returns.

Based on the estimates, for horizons of one-month, one-year, three years and five years, a one-standard-deviation increase in tail risk predicts an increase in future excess returns of 4.5%, 4.0%, 3.7% and 3.2%, respectively. The tail risk variable generates some of the largest R^2 in the cross-section of predictors for every forecast horizon. The importance of the tail risk variable is also documented using bivariate regressions (so controlling for other predictor variables) as well as using out-of-sample forecasting regressions. In short, all these results demonstrate that tail risk is a statistically reliable metric for forecasting market excess returns.

Figure 7: Forecasting the equity risk premium using univariate regressions

	One-month horizon			One-year horizon			Three-year horizon			Five-year horizon		
	Coeff.	t-stat.	R^2	Coeff.	t-stat.	R^2	Coeff.	t-stat.	R^2	Coeff.	t-stat.	R^2
Tail	4.54	2.08	0.7	4.02	2.04	6.1	3.65	2.40	16.6	3.16	2.65	20.9
Book-to-market	2.49	1.14	0.2	3.12	1.34	3.7	2.26	1.12	6.3	2.76	1.82	15.5
Default return spread	2.96	1.36	0.3	0.43	0.57	0.1	0.28	1.22	0.1	0.02	0.18	0.0
Default yield spread	2.82	1.29	0.3	2.93	1.63	3.2	1.90	1.19	4.5	3.04	2.80	14.8
Dividend payout ratio	0.79	0.36	0.0	1.55	0.90	0.9	1.90	1.38	4.4	3.55	3.68	10.4
Dividend price ratio	4.24	1.94	0.7	4.75	2.07	8.5	4.34	2.56	23.1	4.19	3.60	36.5
Earnings price ratio	3.23	1.48	0.4	3.16	1.48	3.8	2.54	1.65	8.0	3.75	2.90	21.5
Inflation	-5.07	-2.33	0.9	-1.67	-1.09	1.1	0.40	0.40	0.2	0.81	0.71	1.2
Long-term return	5.40	2.48	1.1	1.83	3.04	1.3	0.56	2.16	0.4	0.68	2.69	0.9
Long-term yield	1.95	0.89	0.1	3.72	1.70	5.2	4.26	3.48	21.9	4.59	5.17	40.5
Net equity expansion	-0.71	-0.33	0.0	-0.03	-0.01	0.0	0.44	0.27	0.2	-0.14	-0.13	0.0
Stock volatility	-6.24	-2.87	1.4	0.61	0.50	0.1	0.07	0.13	0.0	0.01	0.03	0.0
Term spread	2.28	1.04	0.2	2.57	1.35	2.5	2.53	1.69	7.7	2.18	1.72	9.1
Treasury-bill rate	0.44	0.20	0.0	1.78	0.80	1.2	2.33	1.48	6.3	3.00	2.56	15.6
Var. risk premium	11.22	3.45	4.5	3.32	2.18	3.5	0.63	0.33	0.3	-1.24	-1.90	1.1
Risk Neutral skewness	-0.74	-0.17	0.0	-1.13	-0.34	0.3	-0.35	-0.18	0.1	-0.32	-0.37	0.4
Risk Neutral kurtosis	-1.82	-0.43	0.1	1.56	0.53	0.6	1.16	0.48	1.0	0.56	0.59	1.1

Source: "*Tail Risk and Asset Prices*" by K. Brian & H. Jiang; Table 1, reproduced with permission.[5] This table summarises the results from carrying out univariate forecasting regressions of equity market returns on a number of predictor variables.

Tail risk and the cross-section of stock returns

Following the time-series analysis, the authors then investigate whether tail risk can explain cross-sectional differences in expected stock returns. Put differently, do stocks with higher exposure to market-wide tail risk outperform? For this purpose the authors run a regression for each stock at the end of each month (using a rolling window of 120 months) so to estimate its exposure to the market-wide tail risk variable:

$$E_t[r_{i,t+1}] = \mu_i + \beta_i \lambda_t$$

Then, all stocks are sorted based on their tail risk coefficient, β_i, and grouped in quintile portfolios. The monthly performance of quintile portfolios, as well as of long-short high-minus-low portfolios are summarised in Figure 8. All returns and alphas in this Figure are monthly.

The results show that the high tail-risk quintile portfolio consistently outperforms all other quintile portfolios (the authors also look at 12-month post-formation returns and the results remain both qualitatively and quantitatively unchanged), weighting stocks by market capitalisation or equally, and after controlling for other factors like the Fama and French (1993) value and size factors, the Carhart (1997) momentum factor or the Pastor and Stambaugh (2003) liquidity factor. The authors show that these results are robust even after controlling (using independent double-sorts) for other firm characteristics related to tail risk: firm size, idiosyncratic volatility (Ang, Hodrick, Xing and Zhang 2006), downside beta (Ang, Chen and Xing, 2006) and co-skewness (Harvey and Siddique, 2000).

Stocks with large exposure on the aggregate tail risk variable outperform stocks with low exposure

Figure 8: Tail beta-sorted one-month portfolio returns

	Low	2	3	4	High	High-Low	t-stat
			Equal-weighted				
Average return	1.14	1.24	1.28	1.40	1.45	0.31	2.12
CAPM alpha	0.10	0.31	0.37	0.48	0.47	0.37	2.52
FF alpha	-0.11	0.02	0.09	0.19	0.19	0.30	2.22
FF + Mom alpha	-0.06	0.06	0.11	0.22	0.24	0.29	2.14
FF + Mom + Liq alpha	-0.08	0.06	0.12	0.24	0.26	0.34	2.50
			Value-weighted				
Average return	0.84	0.96	0.98	1.18	1.20	0.36	2.00
CAPM alpha	-0.19	0.03	0.08	0.25	0.18	0.37	2.08
FF alpha	-0.19	-0.04	0.05	0.22	0.27	0.46	2.58
FF + Mom alpha	-0.16	-0.03	0.03	0.18	0.30	0.45	2.22
FF + Mom + Liq alpha	-0.21	-0.03	0.05	0.21	0.35	0.55	2.78

Source: "*Tail Risk and Asset Prices*" by K. Brian & H. Jiang. Table 4 / Panel B, reproduced with permission.[6] The table contains monthly performance statistics for tail risk beta-ranked quintile and long-short portfolios.

Tail risk and economic activity

In the final part of their paper, the authors explore whether the common tail risk variable that has been extracted from cross-sectional data can indeed proxy for the actual tail risk of the entire market or even the economy as a whole. This hinges on the statistical property of power law distributions being stable under aggregation. In that sense, if individual stock return tails do indeed follow a power law, then the market portfolio should inherit the same tail risk dynamics.

The main findings of the analysis are summarised below:

- Increasing tail risk is negatively related to future (after the first two months) skewness and positively related to future kurtosis of market returns.
- The level of tail risk is negatively correlated (-30%) with option-implied skewness and positively correlated (33%) with option-implied kurtosis of S&P 500 (see Bakshi, Kapadia and Madan 2003). Hence, when tail risk rises, the risk neutral market return distribution becomes more negatively skewed.
- When comparing tail risk with the smirk of implied volatility for out-of-the-money put options on S&P 500, a negative correlation of -17% is documented. This becomes even more negative (-53%) when assessed against the average smirk of individual equity options.
- When constructing tail risk metrics across five major industry groups (consumer, manufacturing, technology, healthcare, other), the authors find that these metrics are largely correlated with each other on a time-series basis (correlations are in the range 57%-87%). This constitutes evidence of market-wide common drivers of tail risk that are not industry-specific.
- Return tail risk is also found to be related to fundamental tail risk, as captured by sales growth tail uncertainty. Using the same pooled methodology as above, the authors estimate a market-wide sales growth tail risk variable using quarterly data from Compustat (starting in 1975) and find that return

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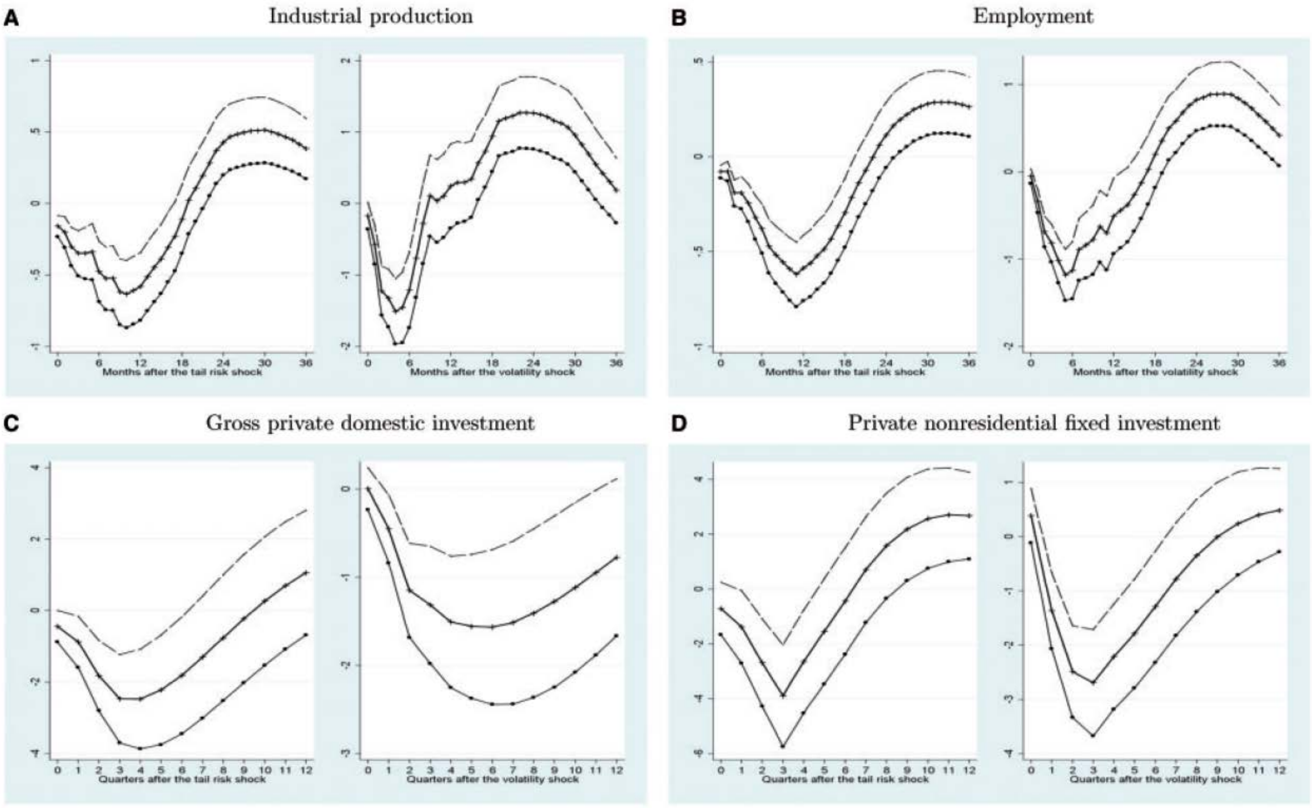
tail risk is statistically significantly correlated with future sales growth tail risk up to three quarters later. In other words, return tail risk leads tail risk measured from sales growth. This should not be surprising, the authors claim, as market prices are much more responsive to news than accounting data.

- Finally, a monthly vector autoregression (VAR) model (Bloom, 2009) is used to identify the impact of time-varying tail risk on macroeconomic aggregates, after, first, controlling for volatility shocks. The model additionally controls for the Federal Fund Rate, log average hourly earnings, the log consumer price index, hours, log employment, and log industrial production. Figure 9 presents the impulse response of industrial production (Panel A), employment (Panel B), and investment (Panels C and D) on a one-standard-deviation shock to tail risk (left panes) and volatility (right panes). In summary, the findings show that a shock to tail risk or to market volatility is related to an immediate contraction in economic activity over the subsequent year. These are distinct effects, as both variables are included in the VAR model (and, as the authors argue, as loosely negatively correlated to each other).

Figure 9: Tail risk impulse response functions



Source: "*Tail Risk and Asset Prices*" by B. Kelly & H. Jiang; Figure 5, reproduced with permission.[7] The figure presents the impact on macroeconomic variables from a one-standard-deviation shock to tail risk on the left and a one-standard deviation shock to volatility on the right. The estimation is done using a VAR model that includes stock market volatility, tail risk, Federal Funds Rate, log average hourly earnings, log CPI, hours, log employment and log industrial production. July 1963 to June 2008.

[7] Copyright © 2014 OUP: https://doi.org/10.1093/rfs/hhu039

"Risk Premia: Asymmetric Tail Risks and Excess Returns"

by Yves Lempérière, Cyril Deremble, Trung-Tu Nguyen, Philip Seager, Marc Potters and Jean-Philippe Bouchard

Do risk premia represent compensation for bearing tail risk?

As opposed to looking at stock returns and a market-wide metric of tail risk, the second paper by Yves Lempérière, Cyril Deremble, Trung-Tu Nguyen, Philip Seager, Marc Potters and Jean-Philippe Bouchard looks at a number of risk premia across asset classes and investigates whether these premia can be explained as compensation for bearing tail risk.

Defining skewness

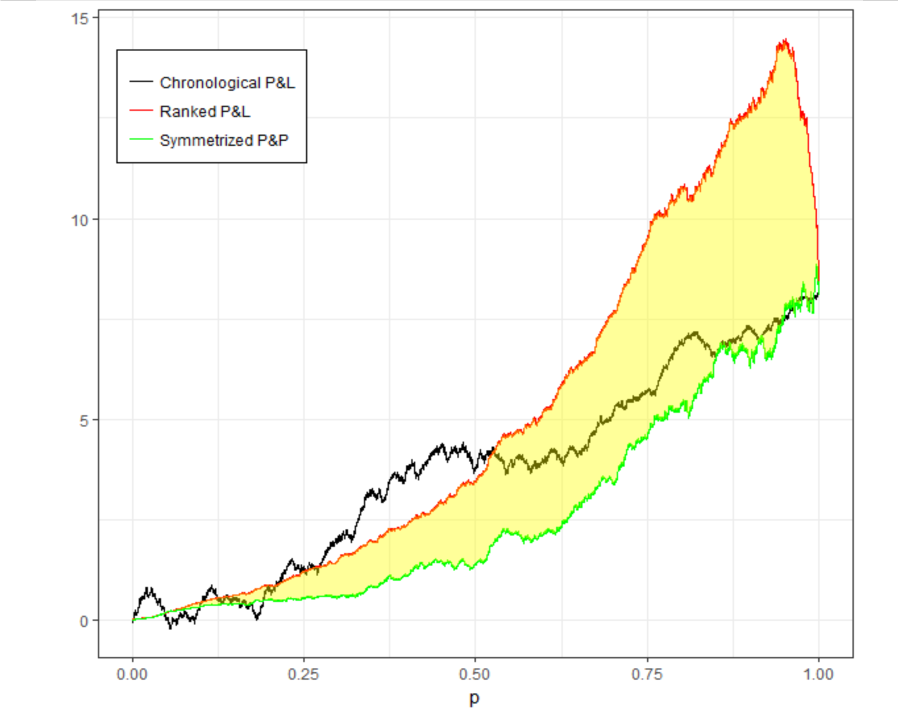
To conduct their analysis, the authors then focus on skewness. However, rather than using the standard definition of skewness, they define a measure based on a ranked P&L returns. The setup for this alternative skewness measure is as follows.

Step one: Rank daily absolute returns and cumulate them

First, the historical daily P&L excess returns[8] of an asset are sorted in terms of their absolute value; the rank index is denoted by k and goes from 1 to N (the total number of returns). Then, the empirical cumulated performance, denoted by $F(p)$, is simply defined by cumulating the ranked returns; p is simply the normalised rank $p = k/N$ and goes from 0 to 1. As an example, in Figure 10 we present $F(p)$ for the (volatility-targeted[9]) S&P 500 index using data from 1928 up to 2016. The Figure additionally includes the chronological P&L for comparative purposes.

The largest absolute returns of S&P 500 are negative; this is an indication of skewness

Figure 10: S&P 500 Ranked P&L



Source: UBS Quanttiative Research. The figure presents the ranked P&L (red line) and symmetrized version (green line) of the S&P 500 since 1928, as a function of $p = k/N$. The black line shows chronological P&L. The area between the two P&L functions, shaded in yellow, is approximately the negative of the skewness measure defined in this paper.

By looking at the actual Ranked P&L graph (red line), it is obvious that the smaller returns in absolute value are generally positive, whereas the largest returns in absolute value are actually negative and therefore indicative of negative skewness.

[8] Returns are computed from indices in excess of the 10-year government rate.
[9] See out January 2017 ARM on volatility-targeting.

In order to capture the negative skewness the authors suggest comparing $F(p)$ to a hypothetical "symmetrized" version $F_s(p)$, if returns where symmetrical around the same mean return. This amounts to having the final points $F(p=1)$ and $F_s(p=1)$ coinciding; technically, as the authors explain, the returns r_t are transformed as $m + \epsilon_t(r_t - m)$, where m is the full-sample average return and $\epsilon_t = \pm 1$ an independent random sign for each t. Figure 10 contains this hypothetical plot for $F_s(p)$ (green line).

Step two: construct a hypothetical return series if the distribution was symmetrical

Along these lines, the difference between the actual cumulative performance of ranked absolute returns $F(p)$, to the hypothetical symmetrized version, $F_s(p)$, can quantify the level of skewness in the returns of the asset.

Step three: estimate the difference

Interestingly, the above methodology can be simplified. As opposed to looking at this difference, we can skip the construction of $F_s(p)$, and only rescale the actual P&L returns so that the average is set to zero and the standard deviation is set to unity (effectively standardising the historical daily returns). In that case, the ranked P&L measure is denoted by $F_0(p)$ (the subscript 0 denotes a zero mean) and its symmetrized function should then be approximately zero by construction. Following this, there is no different to be calculated. Instead, the skewness, denoted by ζ^*, is just defined as the negative of the area underneath the function $F_0(p)$, scaled by 100 to make it of order unity[10]:

A simplified version

$$\zeta^* := -100 \int_0^1 dp\, F_0(p)$$

This concludes the estimation of this new metric of return skewness. According to the authors, several properties of ζ^* make this alternative definition more desirable:

- As opposed to the conventional measure of skewness, ζ^* compares the average amplitude of large negative and positive returns and computes the average differences over all quantiles.
- Existence of the third moment of the distribution is not required.
- Whilst related to classical skewness, it is a claimed to "behave" better over various parametrisations of certain asymmetric distributions.
- It is a more intuitive and robust measure since it is less sensitive to extreme events.

Using this metric of tail risk, the authors then go on and evaluate a number of "risk premia" strategies across various asset classes. These include the Fama and French (1993) equity value and size factors, the Carhart (1997) momentum equity factor, the low-volatility equity factor, risk premia in the fixed income world (credit risk premium) as well as in the FX world (FX carry premium). The research question is always the same; can the various premia be interpreted as compensation for tail risk (i.e. large negative skewness, as measured ζ^*)?

Skewness and Risk Premia

Starting from the **equity factors**, the authors illustrate how inadequate volatility can be at distinguishing between levels of risk, when looking across decile portfolios, ranked by a number of criteria which are the market capitalisation (the size premium), the past 12-month return excluding the recent month (the momentum premium), the earnings to price ratio (the value premium) and past volatility (the low-volatility premium).

1. Equity Factors

[10] For the interested reader, the derivation of this measure is given in the Appendix of the reviewed paper. The Appendix also contains an interesting discussion for the comparison of this measure to the conventional measure of skewness (scaled third central moment).

Except when ranking by volatility (which by construction generates a monotonic behaviour to volatility), the volatility of the various decile portfolios does not exhibit any monotonic behaviour and certainly the top-ranked deciles are not generally much more volatile than the rest of the population. In other words, volatility might not be enough to reflect he risk associated to the various segments of the premia. Instead, ζ^*, by and large, changes monotonically across deciles. However, there are two patterns that emerge:

Top deciles by size or momentum exhibit substantially more negative skewness…

- For size and momentum, the top-ranked deciles exhibit the most extreme negative values of skewness, whereas the bottom-ranked deciles exhibit the less extreme negative value of skewness. It is worth noting that the authors find similar dynamics for size portfolios across a number of countries. This shows that the size and momentum premia could be potentially interpreted as compensation for bearing tail risk.

…not the case for value and low-volatility deciles.

- Conversely, for value and low-volatility, the behaviour is completely opposite. Even though ζ^* still exhibits a monotonic behaviour, this seems to go to the opposite direction, with top-ranked deciles being less negatively skewed.

2. Fixed Income

More risky bonds exhibit larger negative skewness

Looking at a **fixed income universe**, the authors find that bonds of different investment grades (from AAA to CCC) generally exhibit similar volatilities. Instead, their negative skewness captured by the ζ^* metric is almost monotonically increasing as we move from the safe (AAA) to the risky (CCC and below).

3. FX

FX pairs with higher carry exhibit larger negative skewness

Finally looking at the **FX universe** and in particular at FX carry decile portfolios (i.e. ranking currency pairs based on interest rate differentials), the authors find that currency pairs with the largest interest rate differentials (the long side of an FX carry strategy) exhibit larger negative skewness. Again, the ζ^* skewness metric differentiates the decile portfolios more strongly than simple volatility.

To put all these results together, the authors show two things. First, for most strategies, volatility is negatively correlated with the Sharpe ratio (as an extreme example, there is a -0.98 correlation for the low-volatility style). Second, correlation between risk premia and skewness is negative. This illustrates that skewness, as opposed to plain volatility, is an important driver of the various risk premia. The only exception to this rule are the equity value and low-volatility portfolios, as already discussed earlier, and trend-following.

The exceptions:

- **Trend-following**
- **Equity value**
- **Equity low-volatility**

The authors conclude by presenting a scatter plot of the Sharpe ratio versus the skewness (-ζ^*) for all assets and risk premia strategies discussed in their paper. They fit a regression line (which is of the form $S \approx 1/3 - \zeta^*/4$) and show that the majority of strategies fall within the two standard deviation error band around this line. The exceptions are trend-following, equity value (HML) and low-volatility strategies which are clear outliers. Evidently, they do not follow the same patterns as other risk premia strategies. Several reasons are suggested as to why this is the case. In a nutshell, though, the fact that these strategies defy the conclusions found for other strategies points to them being genuine market anomalies, the authors claim.

As a final note, the authors posit why this Sharpe ratio/skewness trade-off exists. The first postulation links the desire for payout streams (e.g. dividends) to price increases and downside risk through the effect of crowdedness. The second explanation relates to option markets and starts with downside risk, which the authors claim already exists, leading to a shortage of option sellers which increases the premium and Sharpe ratio.

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