Low Risk Anomalies?

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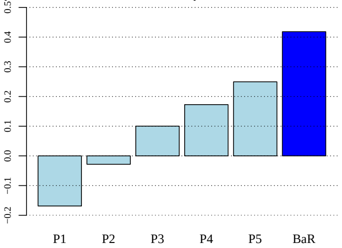
Low risk anomalies?

- Motivation & Background: High Risk ⇔ Low Return
  - Empirical risk-return relation flatter than implied by CAPM or even negative (see, e.g., Brennan, 1971; Black, 1972; Black et al., 1972; Haugen and Heins, 1975)
  - Volatility negatively predicts equity returns (e.g. Ang et al., 2006, 2009)
  - Betting against beta is profitable (e.g. Frazzini and Pedersen, 2014)
- Potential explanations include
  - Frictions to borrowing (e.g. Black, 1972; Brennan, 1971; Frazzini/Pedersen, 2014)
  - Investor mandates (Baker et al., 2011)
  - Macro disagreement (Hong and Sraer, 2014)
  - Demand for lottery stocks (Bali et al., 2015)

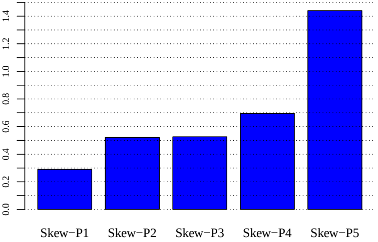
Overview of this paper

- *'Low risk anomalies' do not necessarily pose asset pricing puzzles.*
- Return patterns are consistent with *priced skewness as in Kraus/Litzenberger 1976*.
- Our model implies that high CAPM-βs are prone to overestimating market risk because they ignore the effect of skewness on stock prices.

Alphas of beta-sorted portfolios and BaB



Alphas of BaB when accounting for skewness



- P_1 (P_5) firms with highest (lowest) CAPM beta.
- Skew-P_1 (Skew-P_5) firms with highest (lowest) ex-ante skew.
- Monthly four-factor alphas of betting against beta (BaB).

Model for the market and asset pricing

- Dynamics of the forward market price ($M_{t,T}$), allow for stochastic volatility (κ).
- The market excess return $R := M_{T,T}/M_{0,T} - 1$.
- A representative agent with power utility and constant relative risk aversion (γ).
- Pricing kernel (or SDF or MRS) given by $\mathcal{M} := \frac{(R+1)^{-\gamma}}{\mathbb{E}_0^{\mathbb{P}}\left[(R+1)^{-\gamma}\right]} = \frac{(R+1)^{-\gamma}}{e^{1/2 \int_0^T \kappa_s^2 ds(\gamma-\gamma^2)}}$.
- SDF as a projection on R: $\mathcal{M}(R) := \mathbb{E}^{\mathbb{P}}\left[\mathcal{M} \mid R\right]$.
- The expected return on stock i is given by

$$\mathbb{E}_0^{\mathbb{P}}\left[R_i\right] = \underbrace{\frac{Cov_0^{\mathbb{P}}\left(\mathcal{M}(R), R_i\right)}{Cov_0^{\mathbb{P}}\left(\mathcal{M}(R), R\right)}}_{\text{'true beta'}} \mathbb{E}^{\mathbb{P}}\left[R\right].$$

CAPM and skew-adjusted betas

- In reality, the true SDF is not known.

- A linear CAPM-type pricing kernel arises from first-order SDF approximation.

$$\mathcal{M}_1(R) = a_1 + b_1 R \qquad \text{and} \qquad \mathbb{E}_0^{\mathbb{P}}[R_i] \approx \underbrace{\frac{Cov_0^{\mathbb{P}}(R, R_i)}{V_0^{\mathbb{P}}[R]}}_{\text{CAPM beta}} \mathbb{E}_0^{\mathbb{P}}[R] \, .$$

Skew-adjusted beta

- The second-order approximation to the SDF matches the *skew-aware CAPM* specification of *Kraus/Litzenberger (1976)* and *Harvey/Siddique (2000)*.

$$\mathcal{M}_2(R) = a_2 + b_2 R + c_2 R^2,$$

$$\mathbb{E}_0^{\mathbb{P}}[R_i] \approx \underbrace{\frac{b_2 Cov_0^{\mathbb{P}}(R, R_i) + c_2 Cov_0^{\mathbb{P}}(R^2, R_i)}{b_2 V_0^{\mathbb{P}}[R] + c_2 Cov_0^{\mathbb{P}}(R^2, R)}}_{\text{skew-adjusted beta}} \mathbb{E}_0^{\mathbb{P}}[R].$$

- *The CAPM beta deviates from skew-adjusted beta depending on the market's skewness and the firm's coskewness.*

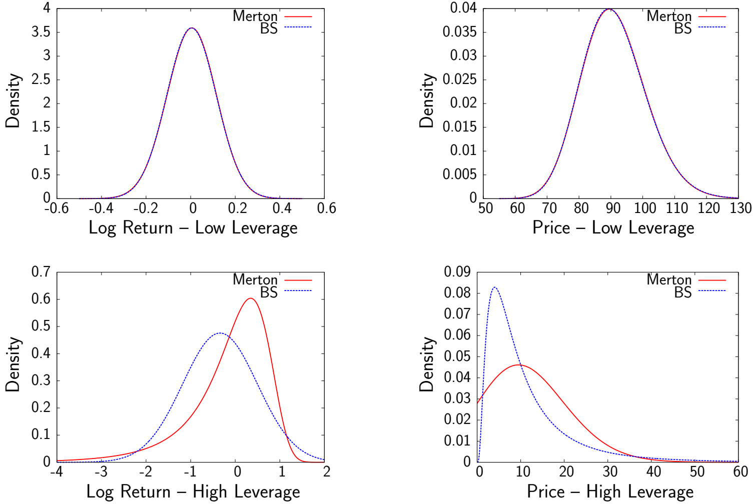
The role of skewness for equity dynamics

- Black and Scholes (1973): equity price follows a GBM.
- *Merton (1974): asset value follows a GBM*,
  - *equity is a European call option on assets* (strike equals D, maturity T)
  - equity can reach the value of zero
  - *time-varying volatility and skewness*
- We model the firm's assets with drift μ and volatility σ as follows

$$\frac{dA_t}{A_t} = \mu dt + \sigma(\rho dW_t^{\mathbb{P}} + \sqrt{1-\rho^2} dB_t^{\mathbb{P}})$$

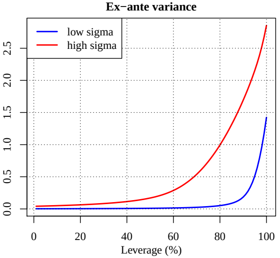
  - *Systematic risk:* Brownian motion $W^{\mathbb{P}}$ as in the market dynamics.
  - *Idiosyncratic risk:* Brownian motion $B^{\mathbb{P}}$ specific to firm i
  - ρ governs the correlation between firm i and the market.

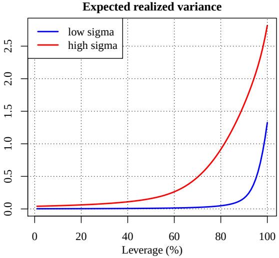
Distribution of Merton vs. Black-Scholes equity



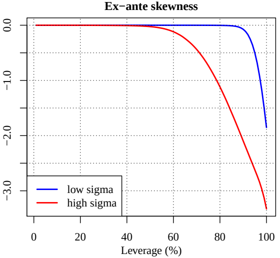
Variance and skew in a multivariate Merton economy

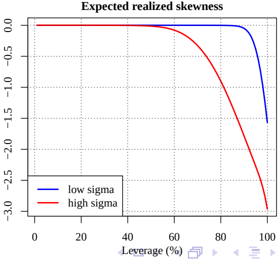
Variance of equity returns increases with credit risk



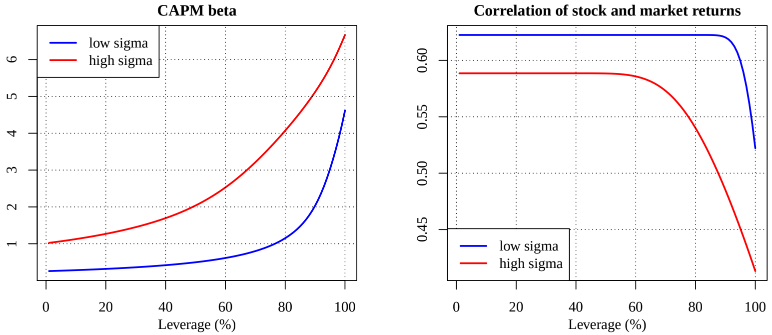


Skewness of equity returns becomes more negative





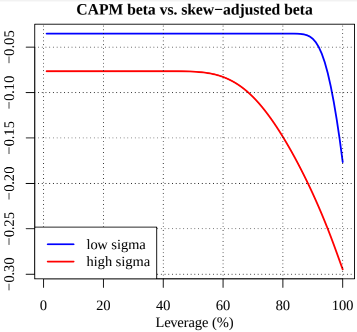
Merton-implied CAPM betas

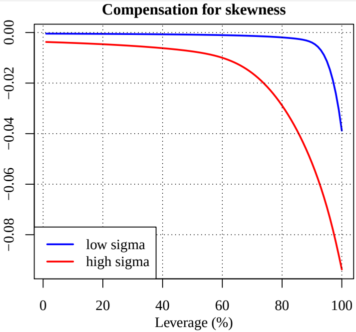


- With *increasing credit risk* (leverage and/or asset volatility)
  - *CAPM beta increases despite returns becoming less correlated with market*

    $\rightarrow$ decreasing stock correlation is outweighed by increasing stock volatility

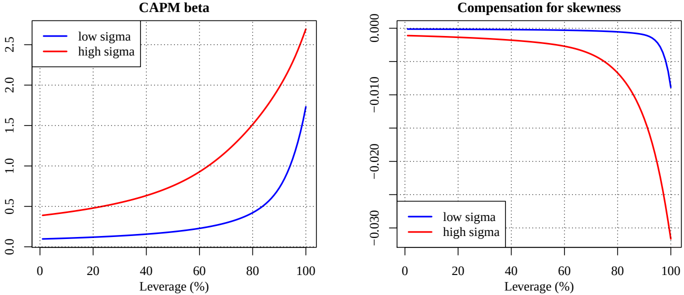
Skew-adjusted betas and compensation for skewness



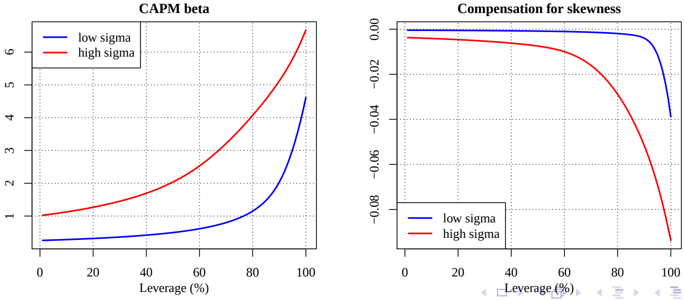


- With *increasing credit risk* (leverage and/or asset volatility)
  - *CAPM beta increasingly overestimates true (skew-adjusted) market risk*
    - CAPM beta vs. skew-adjusted beta: $\beta^{Skew\text{-}adj}/\beta^{CAPM} - 1$
    - skew-adjusted beta increases less than CAPM beta increases
  - *expected return purely due to skewness decreases*
    - 'alpha' relative to the CAPM: $(\beta^{Skew\text{-}adj} - \beta^{CAPM}) \times \mathbb{E}^{\mathbb{P}}[R]$
    - consistent with stocks that are less coskewed requiring lower returns

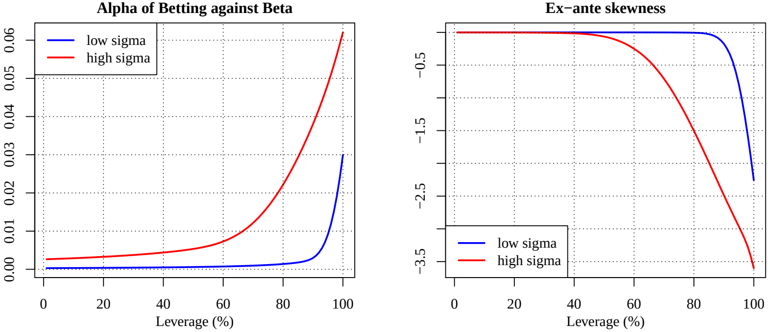
Low correlation between firm asset and market returns



High correlation between firm asset and market returns



Betting against beta and ex-ante skewness



- *Betting against beta:*
  - buy stock with low market correlation
  - sell stock with high market correlation
- *Alpha of betting against beta increases as ex-ante skewness becomes more negative*

Implications for low risk anomalies

- Depending on skewness, high CAPM beta stocks prone to overestimating market risk.
- *Betting against beta (BaB) strategies*
  - should be most profitable for firms with most negative skewness
- *Idiosyncratic volatility:* measurement linked to asset pricing errors
  - high beta stocks: high volatility, prone to overestimation
  - high idio vol predicts negative returns, and more so, the more negative skew.
- *Ex-ante variance* and stock returns
  - U-shaped relation to returns and skewness
  - for firms with negative skew, high variance predicts low returns.
- Implications for the *distress puzzle* directly follow from the model.
- *Simulation study* for a cross-section of 2,000 firms
  - simulation results confirm the skew-implications for low risk anomalies
  - extending our framework to allow for positive skewness does not affect our conclusions on how skewness matters for understanding low risk anomalies.

Data and construction of main variables

- Sample: 400,449 monthly observations, 4,967 firms, 01/1996 to 08/2014.
    - Merged data from OptionMetrics, CRSP, and Compustat.
- Ex-ante moments implied by portfolios of OTM equity options (see, e.g., Bakshi and Madan, 2000; Bakshi et al., 2003; Carr and Wu, 2009; Kozhan et al., 2013; Martin, 2013; Schneider and Trojani, 2014)
    - *Variance*: portfolio that is long OTM puts and long OTM calls.
    - *Skewness*: portfolio long OTM calls, short OTM puts; scale by $VAR_{t,T}^{3/2}$.
- Variables based on historical returns
    - *Conditional CAPM beta* as in Frazzini and Pedersen (2014).
    - *Idiosyncratic volatility* relative to CAPM and to FF3 (Ang et al., 2006).
    - *Conditional coskewness* as in Harvey and Siddique (2000).

Characteristics of of skew-sorted portfolios

- Ex-ante skewness, coskewness, and equity excess returns

  Portfolio P_1 (P_{10}) contains firms with high (low) skewness, monthly rebalancing.

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	HL
Ex-ante skew	17.37	6.50	2.98	0.65	−1.17	−2.79	−4.41	−6.27	−8.91	−17.60	
Harvey/Siddique	−7.33	−6.39	−5.41	−4.17	−3.96	−2.86	−2.89	−2.39	−2.09	−2.45	
Excess return	1.54***	1.39**	0.96*	0.88*	0.78	0.79*	0.76*	0.64	0.47	0.14	1.40***
	[2.71]	[2.47]	[1.90]	[1.85]	[1.60]	[1.74]	[1.75]	[1.55]	[1.21]	[0.40]	[3.85]
FF4 alpha	0.82***	0.65***	0.15	0.06	−0.03	−0.01	−0.05	−0.16	−0.25*	−0.54***	1.36***
	[3.56]	[3.58]	[1.17]	[0.52]	[-0.26]	[-0.08]	[-0.39]	[-1.32]	[-1.93]	[-4.88]	[4.60]

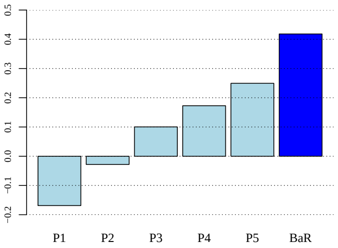
(monthly, excess returns and alphas are in percentage points)

- As predicted by the model, *alphas decrease from the high to the low skew portfolio*.
- Results confirm model implication that *ex-ante skewness is inversely related to coskewness*.
- Consistent with the notion that *firms with more negative coskewness require higher expected equity returns* (Kraus/Litzenberger, 1976; Harvey/Siddique, 2000).

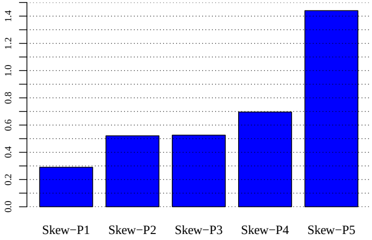
Portfolio characteristics | Equally-weighted returns | Value-weighted returns

Skewness and betting against beta

Beta-sorted portfolios and BaB



BaB when accounting for skewness

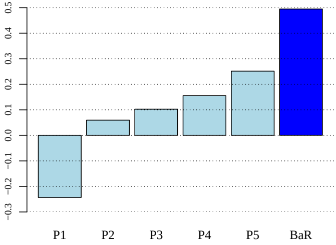


	Betting against Risk		Betting against Risk in Skew Portfolios					
	5 Port.	10 Port	Skew-P_1	Skew-P_2	Skew-P_3	Skew-P_4	Skew-P_5	$P_5 - P_1$
Excess return	0.07	−0.08	−0.06	0.21	0.21	0.28	0.98	1.04***
	[0.11]	[-0.10]	[-0.09]	[0.37]	[0.35]	[0.45]	[1.64]	[2.73]
CAPM alpha	0.87**	0.92*	0.82	0.99**	0.93**	1.00**	1.69***	0.87**
	[2.04]	[1.87]	[1.64]	[2.22]	[2.28]	[2.06]	[4.10]	[2.32]
FF3 alpha	0.76***	0.79**	0.75**	0.84***	0.76**	0.89**	1.60***	0.84**
	[2.61]	[2.23]	[1.99]	[2.77]	[2.29]	[2.38]	[4.57]	[2.02]
FF4 alpha	0.42	0.39	0.29	0.52	0.53	0.70*	1.44***	1.15**
	[1.14]	[0.87]	[0.58]	[1.54]	[1.49]	[1.65]	[4.00]	[2.50]

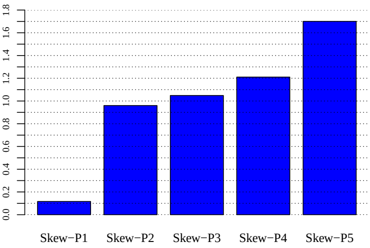
- Profitability of betting against beta increases with downside risk.

Skewness and betting against CAPM idiosyncratic volatility

Portfolios sorted on CAPM idio vola



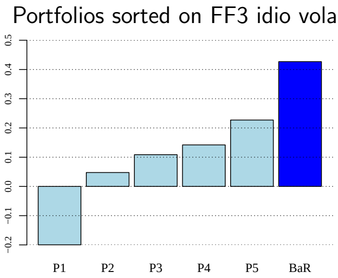
BaR when accounting for skewness

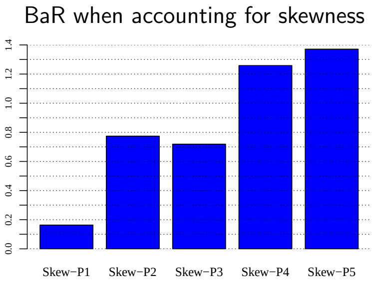


	Betting against Risk		Betting against Risk in Skew Portfolios					
	5 Port.	10 Port	Skew-P_1	Skew-P_2	Skew-P_3	Skew-P_4	Skew-P_5	$P_5 - P_1$
Excess return	0.15	0.32	−0.21	0.57	0.58	0.76	1.44**	1.65***
	[0.25]	[0.46]	[-0.32]	[0.84]	[0.96]	[1.25]	[2.40]	[4.55]
CAPM alpha	0.88**	1.22**	0.61	1.29**	1.26***	1.41***	1.99***	1.38***
	[1.99]	[2.47]	[1.33]	[2.31]	[2.93]	[2.87]	[4.40]	[4.22]
FF3 alpha	0.81***	1.17***	0.52*	1.19***	1.20***	1.35***	1.93***	1.41***
	[3.40]	[4.31]	[1.66]	[3.74]	[4.02]	[4.02]	[6.08]	[4.13]
FF4 alpha	0.49	0.79**	0.12	0.96***	1.05***	1.21***	1.70***	1.58***
	[1.67]	[2.33]	[0.34]	[2.83]	[3.23]	[3.27]	[4.79]	[5.12]

- Profitability of betting against CAPM idiosyncratic volatility increases with downside risk.

Skewness and betting against FF3 idiosyncratic volatility



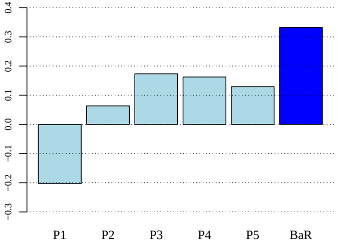


	Betting against Risk		Betting against Risk in Skew Portfolios					
	5 Port.	10 Port	Skew-P_1	Skew-P_2	Skew-P_3	Skew-P_4	Skew-P_5	$P_5 - P_1$
Excess return	0.18	0.29	−0.08	0.48	0.45	0.94*	1.12***	1.20***
	[0.35]	[0.49]	[-0.15]	[0.82]	[0.93]	[1.69]	[2.79]	[3.25]
CAPM alpha	0.81**	1.02**	0.64	1.09**	0.98***	1.49***	1.56***	0.91***
	[2.06]	[2.27]	[1.48]	[2.15]	[2.70]	[3.20]	[3.84]	[2.78]
FF3 alpha	0.75***	0.98***	0.56*	1.00***	0.90***	1.45***	1.60***	1.04***
	[3.58]	[3.72]	[1.85]	[3.40]	[3.60]	[4.44]	[5.58]	[3.41]
FF4 alpha	0.43*	0.57**	0.16	0.77**	0.72***	1.26***	1.37***	1.21***
	[1.80]	[2.26]	[0.52]	[2.44]	[2.74]	[3.48]	[5.77]	[3.90]

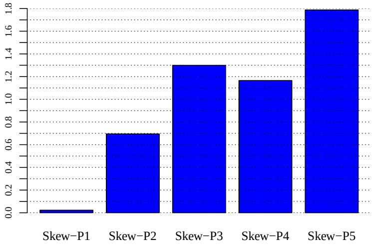
- Profitability of betting against FF3 idiosyncratic volatility increases with downside risk.

Skewness and betting against variance

Portfolios sorted on variance



BaR when accounting for skewness

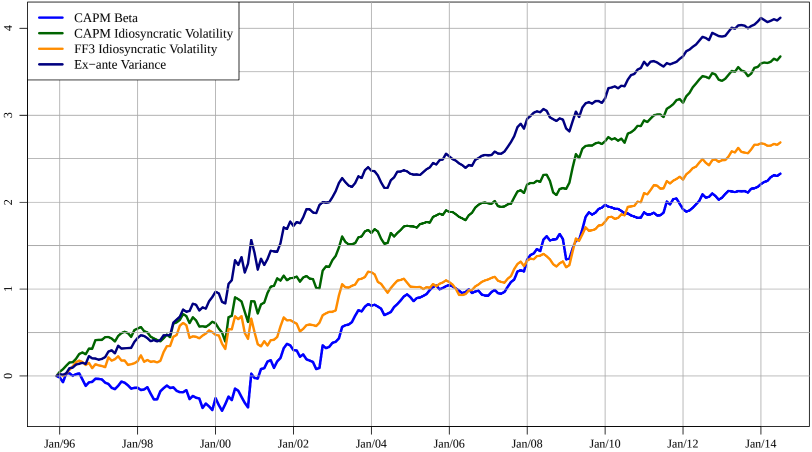


	Betting against Risk		Betting against Risk in Skew Portfolios					
	5 Port.	10 Port	Skew-P_1	Skew-P_2	Skew-P_3	Skew-P_4	Skew-P_5	$P_5 - P_1$
Excess return	0.02	0.06	−0.33	0.35	0.85	0.73	1.52**	1.85***
	[0.03]	[0.08]	[-0.52]	[0.54]	[1.35]	[1.05]	[2.48]	[5.80]
CAPM alpha	0.78*	0.97*	0.54	1.10**	1.58***	1.44***	2.09***	1.55***
	[1.73]	[1.79]	[1.23]	[2.04]	[3.30]	[2.73]	[4.14]	[4.98]
FF3 alpha	0.73***	0.91***	0.47	1.03***	1.54***	1.45***	2.12***	1.65***
	[2.77]	[2.81]	[1.62]	[3.12]	[4.94]	[3.70]	[5.67]	[4.72]
FF4 alpha	0.33	0.39	0.02	0.70**	1.30***	1.17***	1.79***	1.76***
	[1.05]	[1.09]	[0.07]	[2.08]	[3.85]	[2.62]	[5.04]	[4.95]

- Profitability of betting against variance increases with downside risk.

Skew-related return differentials in BaR strategies

- Cumulative excess returns of BaR in Skew-P_5 minus Skew-P_1
  - Time-t cumulative excess return computed as $\sum_{i=0}^{t} r_i$



Insights for the XS of credit risk and equity returns

- Our model endogenizes the role of skewness through credit risk. Empirically, we measure skewness from equity options.
  - Previous evidence shows that options contain information about credit risk. (see, e.g, Hull et al., 2005; Carr and Wu, 2009, 2011; Culp et al., 2015.)
  - Our skew-sorted portfolios exhibit significant HL differentials in leverage.
- When we sort firms by leverage, the results resemble the *'distress puzzle'* (e.g. Dichev, 1998; Vassalou and Xing, 2004; Campbell et al., 2008)
  - The alphas of trading high-minus-low distress firms are negative.
- When we add a 'skew-factor' to the Fama-French-regressions, the returns of trading high-minus-low leverage portfolios
  - significantly load on the skew factor
  - alphas are much smaller and mostly insgnificant

Additional results and robustness checks

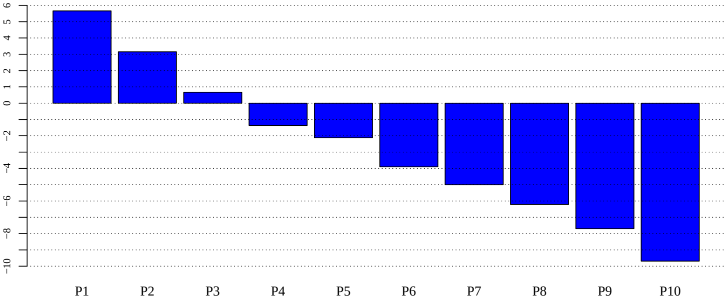
- Ex-ante skew conveys information beyond proxies for lottery-characteristics.
- Betting on skewness most (least) profitable for high (low) beta/volatility stocks.
- Repeating the analysis with the coskew measure of Harvey and Siddque (2000), we find that results are consistent with the model but quantitatively less pronounced.
- Results robust to introducing a lag between measurement of ex-ante skewness and formation of portfolios.
- Results robust to variations in double-sort procedure and return-weighting schemes.

Conclusion

- ‘Low risk anomalies’ do not necessarily pose asset pricing puzzles.
- Patterns are consistent with the notion that skewness matters for asset prices.
  - With more negatively skewed returns, the standard CAPM beta increasingly overestimates a firm’s market risk.
- Conditioning on skewness, risk-adjusted return differentials of betting against beta/volatility are in the range of 1.15% to 1.76% per month (robust over time).
- Additional insights for the distress puzzle.

Realized skewness of skew-sorted portfolios

- Realized skewness (annualized, in %-points)



Back

Characteristics of skew-sorted portfolios

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}
Ex-ante skewness	17.37	6.50	2.98	0.65	−1.17	−2.79	−4.41	−6.27	−8.91	−17.60
Coskewness										
$Cov_0^{\mathbb{P}}(R^2, R_i)$	−1.48	−1.54	−1.43	−1.36	−1.30	−1.22	−1.15	−1.06	−0.99	−0.94
Kraus/Litzenberger	−0.96	−0.98	−0.93	−0.89	−0.86	−0.81	−0.78	−0.72	−0.66	−0.61
Harvey/Siddique	−7.33	−6.39	−5.41	−4.17	−3.96	−2.86	−2.89	−2.39	−2.09	−2.45
CAPM beta	1.08	1.14	1.14	1.13	1.11	1.09	1.06	1.02	0.99	0.93
CAPM idio. vol.	3.13	3.34	3.16	2.97	2.77	2.59	2.41	2.25	2.11	2.02
FF3 idio. vol.	2.63	2.77	2.58	2.42	2.24	2.08	1.94	1.80	1.69	1.62
Ex-ante variance	44.19	38.70	32.58	28.13	24.35	21.50	19.09	17.26	15.97	18.07
Size	1.44	1.89	2.57	3.50	4.85	6.17	8.01	10.08	12.57	11.10
B/M	0.56	0.51	0.49	0.47	0.46	0.45	0.45	0.45	0.46	0.50

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Equally-weighted returns of skew-sorted portfolios

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	HL
Excess return	1.54***	1.39**	0.96*	0.88*	0.78	0.79*	0.76*	0.64	0.47	0.14	1.40***
	[2.71]	[2.47]	[1.90]	[1.85]	[1.60]	[1.74]	[1.75]	[1.55]	[1.21]	[0.40]	[3.85]
Std deviation	8.04	8.05	7.61	7.02	6.68	6.19	5.92	5.45	5.00	4.51	5.20
Skewness	0.51	0.19	−0.26	−0.26	−0.47	−0.51	−0.60	−0.68	−0.73	−1.02	2.25
Sharpe ratio	0.66	0.60	0.44	0.43	0.41	0.44	0.45	0.40	0.32	0.11	0.93
CAPM alpha	0.68**	0.50*	0.10	0.08	−0.00	0.06	0.06	−0.01	−0.12	−0.36*	1.04***
	[2.31]	[1.82]	[0.44]	[0.36]	[-0.01]	[0.30]	[0.35]	[-0.04]	[-0.65]	[-1.69]	[3.57]
FF3 alpha	0.48**	0.35*	−0.04	−0.06	−0.13	−0.09	−0.09	−0.18	−0.29**	−0.57***	1.05***
	[2.07]	[1.73]	[-0.27]	[-0.55]	[-1.11]	[-0.76]	[-0.78]	[-1.48]	[-2.33]	[-4.75]	[3.95]
FF4 alpha	0.82***	0.65***	0.15	0.06	−0.03	−0.01	−0.05	−0.16	−0.25*	−0.54***	1.36***
	[3.56]	[3.58]	[1.17]	[0.52]	[-0.26]	[-0.08]	[-0.39]	[-1.32]	[-1.93]	[-4.88]	[4.60]

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Value-weighted returns of skew-sorted portfolios

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	HL
Excess return	1.29***	1.18*	0.96**	1.06**	0.76	0.97**	0.78**	0.68**	0.55*	0.15	1.14***
	[2.65]	[1.78]	[1.99]	[2.32]	[1.60]	[2.46]	[2.01]	[2.01]	[1.70]	[0.46]	[3.12]
Std deviation	8.18	8.96	7.36	6.83	6.58	5.96	5.59	5.01	4.48	4.42	6.41
Skewness	2.13	0.81	0.21	0.09	−0.33	−0.21	−0.35	−0.57	−0.37	−1.02	4.12
Sharpe ratio	0.55	0.45	0.45	0.54	0.40	0.56	0.48	0.47	0.43	0.12	0.62
CAPM alpha	0.53**	0.27	0.17	0.31	0.00	0.28**	0.11	0.08	0.02	−0.34**	0.87***
	[2.03]	[0.77]	[0.77]	[1.30]	[0.00]	[2.11]	[1.01]	[0.61]	[0.18]	[-2.37]	[2.69]
FF3 alpha	0.31	0.17	0.13	0.31	0.02	0.30**	0.12	0.05	0.00	−0.37***	0.68**
	[1.13]	[0.51]	[0.56]	[1.47]	[0.15]	[2.04]	[1.06]	[0.42]	[0.00]	[-2.88]	[2.08]
FF4 alpha	0.82***	0.68**	0.48*	0.58***	0.24	0.51***	0.21*	0.13	0.07	−0.34**	1.16***
	[3.07]	[2.01]	[1.85]	[2.74]	[1.43]	[4.36]	[1.86]	[1.12]	[0.64]	[-2.39]	[3.42]

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Insights for the distress puzzle

Leverage differentials in skew-sorted portfolios

	Book Leverage		Market Leverage	
	5 Skew-Port.	10 Skew-Port.	5 Skew-Port.	10 Skew-Port.
Leverage Differentials	−3.83***	−4.26***	−4.46***	−4.99***
	[-10.22]	[-10.41]	[-6.06]	[-6.89]

Equity returns of portfolios sorted by leverage: Value-weighted

	Book Leverage		Market Leverage	
	5 Blev-Port.	10 Blev-Port.	5 Mlev-Port.	10 Mlev-Port.
Excess return	−0.33	−0.43	−0.21	−0.32
	[-0.92]	[-1.14]	[-0.48]	[-0.66]
FF4 alpha	−0.58**	−0.73***	−0.60***	−0.78***
	[-2.51]	[-2.98]	[-3.19]	[-2.94]
SKEW beta	−0.49***	−0.35***	−0.37***	−0.43***
	[-4.89]	[-3.14]	[-3.64]	[-4.01]
SKEW FF4 alpha	−0.18	−0.44*	−0.29	−0.43
	[-0.77]	[-1.74]	[-1.49]	[-1.46]

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Skewness and betting against $MAX5$ (Lottery demand)

	Betting against Risk		Betting against Risk in Skew Portfolios					
	5 Port.	10 Port	Skew-P_1	Skew-P_2	Skew-P_3	Skew-P_4	Skew-P_5	$P_5 - P_1$
Excess return	0.39	0.45	0.32	0.73	0.53	0.86	1.06**	0.75**
	[0.76]	[0.75]	[0.54]	[1.34]	[1.08]	[1.61]	[2.30]	[2.29]
Std deviation	8.00	9.47	8.69	8.19	7.42	7.67	6.76	4.68
Skewness	−0.83	−0.97	−0.54	−1.14	−0.52	−1.00	−0.29	0.68
Sharpe ratio	0.17	0.17	0.13	0.31	0.25	0.39	0.55	0.55
CAPM alpha	1.03***	1.20**	1.03**	1.30***	1.09***	1.43***	1.57***	0.53*
	[2.63]	[2.56]	[2.31]	[2.70]	[3.11]	[3.22]	[3.74]	[1.80]
FF3 alpha	0.97***	1.17***	0.98***	1.21***	1.02***	1.39***	1.55***	0.57**
	[4.22]	[4.38]	[3.48]	[4.02]	[3.53]	[4.38]	[5.77]	[2.03]
FF4 alpha	0.73**	0.86***	0.70**	1.07***	0.88***	1.25***	1.38***	0.68**
	[2.49]	[2.90]	[2.46]	[3.25]	[3.07]	[3.57]	[4.98]	[2.15]

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Data

- *OptionMetrics*
  - Daily and monthly option prices/volatility surfaces: 01/1996-07/2014
  - Core analysis: options with one month maturity
- *CRSP and Compustat*
  - Daily firm security prices, 01/1990-08/2014
  - Daily CRSP value-weighted index, 01/1990-08/2014
  - Fundamentals to compute market capitalization and book-to-market ratios
- *Ken French's data library: risk factors and risk free rates*
  - Daily data on MKT, SMB, HML, and RF: 11/1995-07/2014
  - Monthly data on MKT, SMB, HML, UMD, and RF: 01/1996-08/2014
  - Fundamentals to compute market capitalization and book-to-market ratios
- *Sample: 400,449 monthly observations, 4,967 firms, 01/1996 to 08/2014.*
  - For around 61% of sample observations, ex-ante skew is negative.

Measuring higher moments from equity option data

- *Model insight: relation between a firm's coskewness and its ex-ante skewness.*
- Recent research measures ex-ante moments from OTM equity option prices.

  (see, e.g., Bakshi and Madan, 2000; Bakshi et al., 2003; Carr and Wu, 2009; Kozhan et al., 2013; Martin, 2013; Schneider and Trojani, 2014)
- Option-implied variance: portfolio that is long OTM puts and OTM calls
  - We denoted our measure of ex-ante variance by $VAR_{t,T}$.
- *Option-implied skewness: portfolio that is long OTM calls and short OTM puts*
  - We define $SKEW_{t,T}$ as option-implied skewness scaled by $VAR_{t,T}^{3/2}$

    $\rightarrow$ aims to make the measure close to central skewness.

    This measure becomes more negative, the more expensive put options are relative to call options, i.e. if investors are willing to pay high premia for downside risk.
- Approaches differ in portfolio weightings, we follow Schneider and Trojani (2014)

Construction of variables from historical stock returns

- *Conditional CAPM beta: exactly as in Frazzini and Pedersen (2014)*
  - For firm i, estimate the ex-ante beta as

$$\hat{\beta_i^{TS}} = \hat{\rho}_i \frac{\hat{\sigma_i}}{\hat{\sigma_m}}$$

$$\hat{\beta}_i = w \times \hat{\beta_i^{TS}} + (1 - w) \times \hat{\beta}^{XS}$$

    - For ρ_i: rolling 5-year window of 3-day log returns
    - For σ_i and σ_m: rolling 1-year window of 1-day log returns
    - Shrinkage: $\hat{\beta}^{XS} = 1$, $w = 0.6$
- *Idiosyncratic volatility*
  - Relative to the CAPM: use residual variance from above.
  - *Following Ang et al. (2006): variance of daily FF3 residuals over the past month.*
- Measures of *coskewness* based on daily data over rolling 1-year window
  - We estimate $Cov_0^{\mathbb{P}}(R^2, R_i)$.
  - Measure of *Kraus and Litzenberger (1976)*.
  - Measure of *Harvey and Siddique (2000)*.