Can Equity Option Returns Be Explained by a Factor Model? IPCA Says Yes

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Anomalies and risk-adjustment

Many abnormal strategies have been reported for stocks, and many factor models have been proposed.

- E.g., CAPM, FF3, FF5, q4, q5, DHS, SY, etc.

Many documented anomalies in option markets, but very few alternatives to compute effective risk-adjustments.

- E.g., CS (2001), BK (2022), HVX (2020).

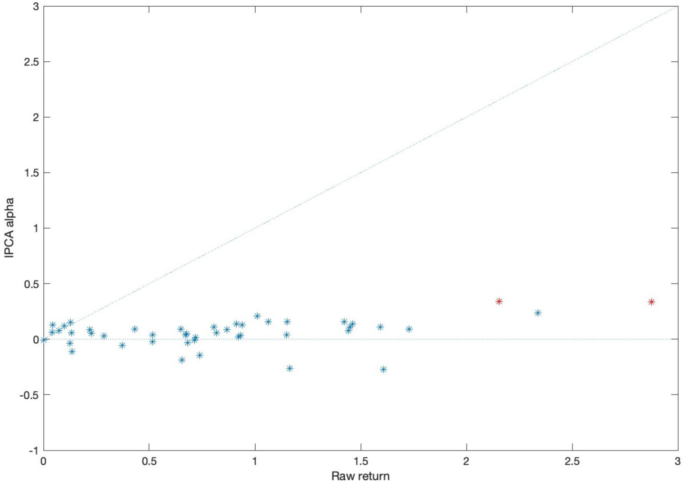
What we do

We focus on equity option strategies that load on volatility (delta-hedged calls) and deliver high realized returns.

We develop a risk-adjustment tool inspired by instrumented principal component analysis (IPCA) of Kelly, Pruitt, and Su (2019).

Expected returns from our IPCA model are very close to their realized counterparts. Accordingly, the most commonly studied option trading strategies display little abnormal profitability.

Alpha vs realized return of long-short portfolios



What does it mean

Our results reaffirm the idea that market efficiency is still a valid framework to think about how prices form in markets.

- Even in a market that is highly segmented and riddled with informational advantages, as the stock option market is.

Data

OptionMetrics from Jan 1996 to Nov 2022. We study expiration to expiration returns.
Two sets of filters:

1. Eliminate contracts that are non-standard or prices that violate basic no-arbitrage bounds. E.g., bid-ask spread is not reasonable.
2. Apply to prices that are used to construct the first leg of the return. We choose options that
   - Are closest to ATM with moneyness between 0.8 and 1.2.
   - Have positive volume or positive open interest.
   - Have mid-point price higher than 25 cents.
   - Have percentage bid-ask spread less than 50%.
   - Have no dividends till the maturity of the option.

Other data are from CRSP and Compustat.

46 predictor variables

1. Contract characteristics such as moneyness, bid-ask spread, open interest, volume, option price, option delta, and implied volatility.
2. Measures of risk-neutral distribution such as model-free implied volatility, model-free implied skewness, model-free implied kurtosis, ATM slope, and ATM term.
3. Measures of physical distribution of returns such as stock returns, volatility, autocorrelation, skewness, and kurtosis.
4. Stock returns predictors such as book-to-market, profitability, and relative short interest.

Delta-hedged call option portfolio returns (1)

$$\text{DHCall}_{t+1} = \frac{(C_{t+1} - C_t) - \sum_{n=0}^{N-1} \Delta_{d_n} (S_{d_{n+1}} - S_{d_n})}{\Delta_t S_t - C_t} - R_{f t+1}.$$

	Construction	Return		Return w/ TC	
Moneyness	1−10	**0.38**	**(3.60)**	−0.86	(−8.13)
Bid-ask spread	1−10	**0.71**	**(8.07)**	−0.13	(−1.50)
Open interest	1−10	0.04	(0.66)	−0.59	(−9.84)
Delta	10−1	**0.22**	**(2.58)**	−0.68	(−7.52)
Vega	10−1	**1.44**	**(14.83)**	**0.47**	**(5.02)**
Gamma	1−10	**0.67**	**(7.09)**	−0.25	(−2.69)
Volume	10−1	**0.23**	**(3.11)**	−0.40	(−5.28)
Option price	10−1	**0.65**	**(5.72)**	−0.12	(−1.09)
IV ATM	1−10	**2.34**	**(17.94)**	**1.40**	**(10.95)**
IV slope	10−1	**2.15**	**(25.53)**	**0.91**	**(10.46)**
IV term	10−1	**1.42**	**(15.94)**	**0.43**	**(4.84)**
IV vol	1−10	**1.45**	**(15.65)**	**0.61**	**(6.81)**
MFvol	1−10	**1.16**	**(5.16)**	**0.69**	**(3.13)**
MFskew	1−10	**0.83**	**(4.98)**	**0.42**	**(2.54)**
MFkurt	10−1	**0.74**	**(4.41)**	0.33	(1.97)
Stock return	10−1	0.04	(0.46)	−0.93	(−9.30)
Stock return11	10−1	**0.29**	**(2.91)**	−0.71	(−7.09)
RV	1−10	**1.06**	**(9.23)**	0.22	(1.94)
Rskew	1−10	**0.14**	**(2.23)**	−0.74	(−12.62)
Rkurt	1−10	**0.91**	**(14.48)**	**0.15**	**(2.45)**
Turnover	1−10	0.13	(1.32)	−0.66	(−6.68)

	Construction	Return		Return w/ TC	
IdiosynVol	1−10	**1.15**	**(11.18)**	**0.33**	**(3.26)**
Max10	1−10	**0.94**	**(8.35)**	0.11	(0.99)
Autocorrelation	10−1	0.07	(1.24)	−0.72	(−12.25)
RV−IV	10−1	**2.87**	**(24.51)**	**1.73**	**(14.94)**
RV−MFvol	10−1	**1.64**	**(7.49)**	**1.11**	**(5.16)**
Rskew−MFskew	1−10	0.11	(0.73)	−0.31	(−2.13)
Rkurt−MFkurt	1−10	**1.00**	**(8.03)**	**0.65**	**(5.22)**
BM	10−1	0.13	(1.39)	−0.75	(−8.33)
Profitability	10−1	**0.92**	**(11.71)**	0.03	(0.41)
InstOwn	10−1	**0.93**	**(12.10)**	0.03	(0.38)
MarketCap	10−1	**1.59**	**(16.74)**	**0.67**	**(7.22)**
RSI	10−1	0.10	(1.56)	−0.63	(−9.77)
Assets	10−1	**1.46**	**(14.59)**	**0.64**	**(6.71)**
Debt	10−1	**0.68**	**(8.82)**	0.04	(0.50)
Leverage	10−1	0.00	(0.06)	−0.84	(−15.11)
CashFlowVar	1−10	**0.72**	**(9.11)**	−0.01	(−0.16)
Cash to asset	1−10	**0.87**	**(9.42)**	−0.04	(−0.43)
AnalystDisp	10−1	**0.52**	**(8.18)**	−0.49	(−7.82)
1yr NewIss	1−10	**0.43**	**(5.58)**	−0.34	(−4.45)
5yr NewIss	1−10	**0.65**	**(8.33)**	−0.09	(−1.25)
Profit margin	10−1	**1.15**	**(13.37)**	**0.25**	**(3.05)**
Stock price	10−1	**1.73**	**(16.09)**	**0.74**	**(7.03)**
ROE	10−1	**0.82**	**(11.09)**	−0.07	(−0.99)
ExternalFin	1−10	**0.52**	**(6.10)**	−0.31	(−3.70)
Z score	10−1	**0.68**	**(7.99)**	−0.29	(−3.62)

Option portfolio returns (2)

1. 39 have statistically significant average returns.
   - RV−IV of Goyal and Saretto (2009) has monthly return of 2.87% (t-statistic = 24.51).
2. 16 have statistically significant average return after adjusting for transaction costs (ESPR/QSPR = 30%).
   - RV−IV has monthly return of 1.73% (t-statistic = 14.94).

Implication: Massive inefficiency in the option market.

Enter Sandman (sorry $\ddot\smile$, IPCA)

$$
\begin{aligned}
R_{it+1} &= \alpha_{it} + \beta_{it}' F_{t+1} + E_{it+1} \\
&= \left(Z_{it}'\Gamma_{\alpha}\right) + \left(Z_{it}'\Gamma_{\beta}\right) F_{t+1} + E_{it+1}.
\end{aligned}
$$

- Fs are K latent factors.
- α_{it} and β_{it} are asset specific time-varying intercept and factor loadings.
- Z_{it} are L observable characteristics.
- $L \times 1$ vector Γ_{α} and $L \times K$ matrix Γ_{β} define the mapping from characteristics to mispricing and risk factor exposures.

Why IPCA?

- Allows for very flexible structure: particularly important is time-varying betas.
- Allows for inclusion of completely different contracts moneyness and maturity.
  - Same factors can price contracts with different characteristics because variation in betas is directly driven by characteristics.
- Very hard to beat (in- or out-of-sample) in terms of pricing errors.

Estimation

Define $W_t = Z_t' Z_t / N_{t+1}$, $X_{t+1} = Z_t' R_{t+1} / N_{t+1}$, $\tilde{F}_{t+1} = [F_{t+1} : 1]'$, and $\Gamma = [\Gamma_\beta : \Gamma_\alpha]$. Then FOCs are:

$$\begin{aligned}\hat{F}_{t+1} &= \left(\hat{\Gamma}_\beta' W_t \hat{\Gamma}_\beta\right)^{-1} \hat{\Gamma}_\beta' (X_{t+1} - W_t \hat{\Gamma}_\alpha) \\ \text{vec}\left(\hat{\Gamma}'\right) &= \left(\sum_{t=1}^{T-1} W_t \otimes \hat{\tilde{F}}_{t+1} \hat{\tilde{F}}_{t+1}'\right)^{-1} \sum_{t=1}^{T-1} X_{t+1} \otimes \hat{\tilde{F}}_{t+1}.\end{aligned}$$

- X_{t+1} are returns on a set of L managed portfolios.
- Estimation is quick as it involves iterated OLS only.
- Inference via bootstrap.

Pricing performance metrics

$$\text{Total } R^2 = 1 - \frac{\sum_{it}\left(R_{it+1} - Z'_{it}\hat{\Gamma}_\beta \hat{F}_{t+1}\right)^2}{\sum_{it} R^2_{it+1}}$$

$$\text{Time Series } R^2 = \frac{1}{\sum_i T_i}\sum_i T_i R_i^2;\ \text{where } R_i^2 = 1 - \frac{\sum_t\left(R_{it+1} - Z'_{it}\hat{\Gamma}_\beta \hat{F}_{t+1}\right)^2}{\sum_i R^2_{it+1}}$$

$$\text{Cross Section } R^2 = \frac{1}{T}\sum_t R_t^2;\ \text{where } R_t^2 = 1 - \frac{\sum_i\left(R_{it+1} - Z'_{it}\hat{\Gamma}_\beta \hat{F}_{t+1}\right)^2}{\sum_i R^2_{it+1}}$$

$$\text{Relative Pricing Error} = \frac{\sum_i \alpha_i^2}{\sum_i \bar{R}_i^2};\ \text{where } \alpha_i = \frac{1}{T_i}\sum_t\left(R_{it+1} - Z'_{it}\hat{\Gamma}_\beta \hat{F}_{t+1}\right).$$

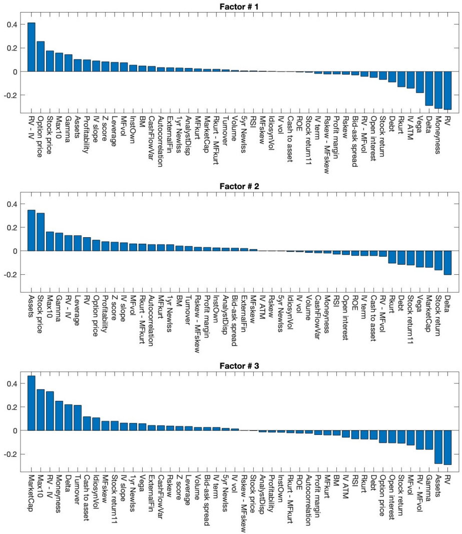
IPCA performance (In-sample)

	Number of factors				
	1	2	3	4	5
Stock Level Option Positions:					
Total R^2	8.77	11.54	12.22	12.75	13.22
Time Series R^2	12.11	15.04	15.68	15.87	16.16
Cross Section R^2	8.69	10.84	11.38	11.86	12.27
Relative Pricing Error	78.46	73.68	72.74	71.80	71.20
Managed Portfolios:					
Total R^2	63.93	82.45	87.60	89.41	91.23
Time Series R^2	40.65	65.15	73.43	76.48	80.33
Cross Section R^2	53.45	70.50	75.70	78.38	80.58
Relative Pricing Error	24.46	0.38	0.23	0.18	0.15
Bootstrap test:					
W_α p-value	0.03	0.93	0.86	0.80	1.00
Economic test:					
# Unpriced Factors	0	0	0	1	3

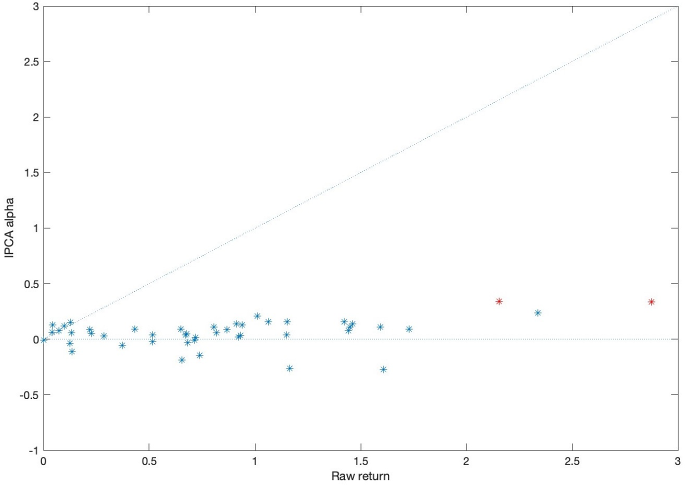
IPCA performance (Out-of-sample)

	Number of factors				
	1	2	3	4	5
Stock Level Option Positions:					
Total R^2	6.70	8.74	9.32	9.77	10.26
Time Series R^2	0.08	−6.76	−6.15	−9.12	−19.25
Cross Section R^2	6.65	8.32	8.87	9.28	9.77
Relative Pricing Error	81.75	77.73	76.99	76.39	75.32
Managed Portfolios:					
Total R^2	54.39	78.23	83.27	85.01	87.65
Time Series R^2	28.22	57.52	66.42	68.95	73.94
Cross Section R^2	47.19	63.92	69.62	72.14	75.00
Relative Pricing Error	48.16	9.47	5.26	6.06	5.16

Interpreting IPCA betas (IPCA Γ_β)



Alpha again



An example of risk adjustment for the RV−IV strategy

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Ret	−2.89	−1.14	−0.81	−0.59	−0.52	−0.37	−0.25	−0.20	−0.06	−0.02
E(Ret)	−2.41	−1.46	−1.04	−0.75	−0.59	−0.36	−0.22	−0.11	0.02	0.13
α_{IPCA}	−0.48	0.32	0.24	0.16	0.07	−0.01	−0.03	−0.09	−0.07	−0.14
β_{F1} E(F1)	−2.63	−1.70	−1.27	−0.99	−0.84	−0.61	−0.49	−0.40	−0.31	−0.27
β_{F2} E(F2)	0.20	0.20	0.19	0.19	0.19	0.19	0.20	0.20	0.22	0.25
β_{F3} E(F3)	0.02	0.04	0.04	0.04	0.06	0.06	0.07	0.09	0.11	0.15
RV−IV	−1.75	−1.04	−0.68	−0.39	−0.11	0.13	0.39	0.68	1.04	1.75

Interpreting IPCA betas (Characteristic importance)

RV−IV	0.54 (0.00)	Open interest	0.12 (0.02)
MarketCap	0.49 (0.00)	Z score	0.12 (0.04)
Assets	0.46 (0.00)	IdiosynVol	0.11 (0.07)
RV	0.45 (0.05)	1yr NewIss	0.09 (0.02)
Max 10	0.42 (0.00)	MFskew	0.08 (0.55)
Delta	0.42 (0.03)	RSI	0.08 (0.15)
Moneyness	0.40 (0.02)	BM	0.08 (0.17)
Stock price	0.37 (0.08)	MFkurt	0.07 (0.60)
Option price	0.29 (0.69)	Autocorrelation	0.07 (0.02)
Gamma	0.26 (0.25)	Rkurt−MFkurt	0.07 (0.45)
Vega	0.23 (0.39)	CashFlowVar	0.06 (0.08)
Turnover	0.22 (0.01)	InstOwn	0.06 (0.14)
Stock return	0.21 (0.04)	ExternalFin	0.06 (0.11)
Rkurt	0.18 (0.00)	Profit margin	0.05 (0.20)
RV−MFvol	0.17 (0.36)	IV term	0.05 (0.22)
Debt	0.16 (0.06)	Bid-ask spread	0.05 (0.52)
MFvol	0.16 (0.48)	Rskew	0.05 (0.16)
Leverage	0.16 (0.07)	ROE	0.05 (0.20)
IV ATM	0.15 (0.45)	AnalystDisp	0.04 (0.17)
Stock return11	0.14 (0.15)	Rskew−MFskew	0.04 (0.69)
IV slope	0.13 (0.03)	Volume	0.03 (0.06)
Profitability	0.13 (0.04)	5yr NewIss	0.02 (0.62)
Cash to asset	0.12 (0.01)	IV vol	0.02 (0.79)

Interpreting IPCA latent factors

	Panel A: Difference of means			Panel B: Linear regression slope		
	F1	F2	F3	F1	F2	F3
Market Return	−0.34	0.35	0.35	−0.45	0.50	0.22
	(−2.10)	(2.16)	(4.29)	(−2.96)	(3.18)	(4.30)
ΔVIX	−0.59	0.38	0.40	−0.55	0.55	0.20
	(−3.95)	(2.32)	(4.91)	(−5.28)	(3.64)	(4.43)
Tail Risk	−0.46	0.26	−0.34	−0.42	0.15	−0.25
	(−2.80)	(1.60)	(−2.90)	(−4.98)	(1.61)	(−3.88)
Vol Risk	1.32	−0.72	−0.27	0.65	−0.82	−0.21
	(8.68)	(−4.39)	(−2.60)	(5.85)	(−11.11)	(−2.05)
Skew Risk	−0.81	−0.03	−0.23	−0.36	−0.02	−0.15
	(−4.92)	(−0.20)	(−2.11)	(−4.75)	(−0.37)	(−2.85)
Kurt Risk	−0.81	−0.09	−0.27	−0.36	−0.04	−0.16
	(−4.79)	(−0.54)	(−2.27)	(−5.00)	(−0.66)	(−3.07)
ICRFac	−0.05	0.37	0.01	−0.03	0.28	−0.06
	(−0.38)	(2.65)	(0.10)	(−0.41)	(3.78)	(−0.95)
Average Gamma	−0.96	−0.40	−0.01	−0.60	−0.22	−0.10
	(−6.36)	(−2.25)	(−0.09)	(−7.21)	(−2.14)	(−1.17)
Average Vega	−0.49	0.23	−0.27	−0.10	0.12	−0.20
	(−2.76)	(1.27)	(−2.44)	(−1.05)	(1.13)	(−3.28)

Conclusion

Explaining the returns from option position is a daunting task as option returns are extremely volatile and carry sizable liquidity premia.

We unify the knowledge accumulated in the extant literature about cross-sectional characteristics that predict option returns and recent advances in asset pricing methods.

We show that the reports of the death of market efficiency in options markets are greatly exaggerated.