# Implied Volatility Sentiment: A Tale of Two Tails

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**ABSTRACT**

We propose a sentiment measure jointly derived from out-of-the-money index puts and single stock calls: implied volatility (IV-) sentiment. In contrast to implied correlations, our measure uses information from the tails of the risk-neutral densities from these two markets rather than across their entire moneyness structures. We find that IV-sentiment measure adds value over and above traditional factors in predicting the equity risk premium out-of-sample. Forecasting results are superior when constrained ensemble models are used vis-à-vis unregularized machine learning techniques. In a mean-reversion strategy, our IV-sentiment measure delivers economically significant results, with limited exposure to a set of cross-sectional equity factors, including Fama and French's five factors, the momentum factor and the low-volatility factor, and seems valuable in preventing momentum crashes. Our novel measure reflects overweight of tail events, which we interpret as a behavioral bias. However, we cannot rule out a risk-compensation rationale.

Keywords: Sentiment, implied volatility, equity-risk premium, reversals, predictability, machine learning.

JEL classification: G12, G14, G17.

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# C Appendix: Empirical appendix

## C.1 Performance contribution of long- and short-legs of *IV-sentiment* strategy

As a robustness check to *IV-sentiment* high frequency strategy presented in Section 3.1, we analyze whether our *IV-sentiment* high-frequency trading strategy performs well due to both its legs or whether its merit is concentrated in either the long- or the short-leg. We separate the performance of the two legs of the strategy as if they were two different strategies and we compute individual performance statistics. In order to visualize the results, IR boxplots separately for the three option maturities are shown in Figure 6.

[Please insert Figure 6 about here]

The distributions of IRs for the long positions are shown in the plots at the upper part, while the distributions of IRs for the shorts are shown at the bottom. We note that the dispersion of IRs from the short-leg is much higher than from the long-leg; outliers are much more frequent in the short-leg. We find that the median IRs of long-legs are substantially higher than for short-legs. The IR distributions of the short positions seem slightly skewed to the negative side, whereas for the long positions they seem skewed to the positive side. These results indicate that the merit of our *IV-sentiment* strategy is concentrated in its buy- rather than its sell-signal.

Figure 6 suggests that other IV-based strategies also have their long-legs outperforming their short-legs. This finding suggests that extreme bearish sentiment signals may be more reliable than extreme bullish sentiment signals. One explanation for this finding is the fact that the IV may be more reactive on the downside, due to the *leverage effect*[37]. In contrast, on the upside, a higher IV led by the bidding of call options might be offset by an overall lower IV. Our results are partially in line with the literature on cross-sectional returns and skew measures. Barberis and Huang (2008) suggest that stocks that have a high skew tend to have high subsequent returns, whereas for a call with a high skew this relation is inverse. However, other studies, such as Cremers and Weinbaum (2010), suggest that the relation between returns and volatility skews has the opposite direction. Assuming that there are systematic reasons for OTM implied volatilities across stocks to move in tandem, e.g., market risk, as suggested by Dennis and Mayhew (2002) and Duan and Wei (2009), then the logical consequence from the cross-sectional relation between the implied skew and returns would be that the overall equity market should reverse following times of extremely high skews.

[37]The *leverage effect* refers to the typically observed negative correlation between equity returns and its changes in volatility.

## C.2 Full results of section *IV-Sentiment* versus *Single-market IV-Sentiment*

In Section 5.1 we provide evidence that *Single-market IV-Sentiment* strategies perform more poorly than *IV-Sentiment* as a trading strategy, as our measure for sentiment seems to contain different information than IV skews from either index or single stock options in isolation. Full results for the comparison of these strategies are provided by Table 8. In Section 5.1 we also test whether our *IV-Sentiment* strategy further explain beyond established equity factors. Full results for the estimation of Eqs. (5c) and (5d) are provided by Table 9:

[Please insert Table 8 about here]

[Please insert Table 9 about here]

## C.3 Full results of section *controlling for investors' optimism*

In Section 5.2 we provide evidence that investor sentiment is linked to time-varying preferences for lottery tickets even after controlling for time-varying investor optimism. We do this to prove that overweighting of tail events during periods of high sentiment reflects a behavioral bias rather than change in beliefs only. Full results for the estimation of Eqs. (22) and (23) are provided by the Tables 10 and 11:

[Please insert Table 10 about here]

[Please insert Table 11 about here]

## C.4 Full results of section *Implied correlation and correlation risk premium factors*

In Section 5.3, we attempt to better understand the difference between *IV-sentiment* and the implied correlation (IC) and the correlation risk premia (CRP) measures. For that purpose, we estimate a correlation matrix of the Buss et al. (2017) factors *IV-sentiment* measures and *DGspreads* using our full sample. This estimate correlation matrix is available in Figure (7). Buss et al. (2017) compute ICs for the standard maturities of 30, 91, 182, 273, and 365 days. CRPs are computed as IC minus the realized correlation from daily returns from the historical window equal to the maturity of the options used for a given IC.

[Please insert Figure 7 about here]

To explain the difference between IC and *IV-sentiment*, we designed Eq. (24). Complete results for the estimation of this equation are provided by Table 12:

[Please insert Table 12 about here]

## Table 8: *IV-sentiment* and *Single-market IV-sentiment* strategies

Panel A reports the results of contrarian pair-trade strategies based on our *IV-sentiment 90-100* indicator and on other *Single-market IV-sentiment* measures, namely the *IV-Sentiment-Single* indicator (produced from three-month single stock options and 90-110 moneyness levels) and the *IV-Sentiment-Index* indicator (produced from three-month index options and 90-110 moneyness levels). These IV-based strategies use 252 days as the look-back period and +/- two standard deviations as convergence thresholds. Panel B reports the correlation coefficients of daily returns estimated over the period between January 2, 1998 and December 4, 2015, for the same strategies reported in Panel A. Panel C reports the co-skewness and the conditional co-crash (CCC) probabilities of the three-month *IV-sentiment 90-110* with the other strategies, which indicate the degree of tail-dependence among them.

| Panel A - Back-test results | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | IV-sentiment 90-110 | IVSentSingle 90-110 | IVSentSingle 80-120 | IVSentIndex 90-110 | IVSentIndex 80-120 |
| Average return | 0.20% | -0.29% | -0.15% | 0.10% | 0.02% |
| Volatility | 0.71% | 0.80% | 0.79% | 0.65% | 0.66% |
| Information ratio | 0.29 | -0.36 | -0.19 | 0.15 | 0.03 |
| Skewness | 0.10 | -0.15 | -0.11 | -0.01 | -0.10 |
| Kurtosis | 15.84 | 18.89 | 20.13 | 23.45 | 22.72 |
| Max drawdown | -1.7% | -5.8% | -4.7% | -2.0% | -1.8% |
| Avg recovery time (in years) | 0.43 | 3.19 | 1.99 | 0.48 | 0.66 |
| Max daily drawdown | -0.55% | -0.47% | -0.47% | -0.47% | -0.47% |
| Panel B - Correlation matrix | IV-sentiment 90-110 | IVSentSingle 90-110 | IVSentSingle 80-120 | IVSentIndex 90-110 | IVSentIndex 80-120 |
| IVSent 90-110 | 1.00 | 0.28 | 0.32 | 0.45 | 0.50 |
| IVSentSingle 90-110 | 0.28 | 1.00 | 0.90 | 0.33 | 0.48 |
| IVSentSingle 80-120 | 0.32 | 0.90 | 1.00 | 0.39 | 0.53 |
| IVSentIndex 90-110 | 0.45 | 0.33 | 0.39 | 1.00 | 0.84 |
| IVSentIndex 80-120 | 0.50 | 0.48 | 0.53 | 0.84 | 1.00 |
| Panel C - Tail dependence with IV-sentiment | IV-sentiment 90-110 | IVSentSingle 90-110 | IVSentSingle 80-120 | IVSentIndex 90-110 | IVSentIndex 80-120 |
| Co-skewness | 5.3E-12 | 2.2E-12 | 5.5E-12 | 1.5E-11 | 1.1E-11 |
| 1% cond. crash prob. | 100% | 31% | 33% | 42% | 53% |
| 2% cond. crash prob. | 100% | 42% | 46% | 46% | 56% |
| 5% cond. crash prob. | 100% | 48% | 55% | 48% | 52% |

## Table 9: Regression results: IV-sentiment, equity factors and single-market IV-sentiment strategies

This table reports the regression results for Eqs. (5c) and (5d) with the inclusion of *IVSentSingle* and *IVSentIndex* as explanatory variables. The dependent variable is the stream of returns produced by the contrarian strategy based on our *IV-sentiment 90-110* indicator, while the explanatory variables are equity (cross-sectional) factors, namely: the market (Mkt-Rf), size (SMB), value (HML), profitability (RMW), investment (CMA), momentum (WML) and low- versus high-beta (BAB). The additional explanatory variables *IVSentSingle* and *IVSentIndex* are, respectively, the stream of returns produced by the contrarian strategy based on the *IV-Sentiment-Single* indicator (produced from three-month single stock options and 90-110 moneyness levels) and the *IV-Sentiment-Index* indicator (produced from three-month index options and 90-110 moneyness levels). Panel A reports the regression results using daily data produced by Eq. (5c). Panel B reports the regression results using monthly data produced by Eq. (5d), which also includes the BAB (Betting Against Beta) factor suggested by Frazzini and Pedersen (2014). We report standard errors in brackets. Asterisks ***, **, and * indicate significance at the one, five, and ten percent level, respectively.

| **Panel A - Daily data** | | | | | **Panel B - Monthly data** | | | |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0.000 | 0.000 | 0.000 | 0.000* | 0.007* | 0.000 | 0.000 | 0.000 |
| | (0.000) | (1.332) | (0.000) | (0.000) | (0.004) | (0.000) | (0.000) | (0.000) |
| Mkt-RF | 0.003*** | -0.003*** | -0.003*** | -0.006*** | 0.072 | -0.013** | -0.005 | -0.012** |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.104) | (0.006) | (0.005) | (0.005) |
| SMB | 0.007*** | 0.007*** | 0.005*** | 0.005*** | -0.107 | -0.006 | -0.008 | -0.011 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.152) | (0.009) | (0.008) | (0.007) |
| HML | -0.003** | -0.003** | -0.003*** | -0.003*** | -0.271 | -0.015 | -0.021** | -0.016* |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.180) | (0.011) | (0.009) | (0.009) |
| WML | -0.007*** | -0.003*** | -0.008*** | -0.006*** | -0.179* | -0.002 | -0.009* | -0.004 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.094) | (0.006) | (0.005) | (0.005) |
| RMW | -0.002 | -0.004** | -0.007*** | -0.007*** | -0.130 | 0.006 | -0.010 | -0.006 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.220) | (0.011) | (0.010) | (0.010) |
| CMA | 0.012*** | 0.011*** | 0.007*** | 0.007*** | 0.624** | 0.036** | 0.023* | 0.021 |
| | (0.002) | (0.002) | (0.002) | (0.002) | (0.245) | (0.015) | (0.013) | (0.013) |
| BAB | | | | | -0.186 | -0.020*** | -0.004 | -0.010 |
| | | | | | (0.126) | (0.007) | (0.006) | (0.006) |
| IVSentSingle | | 0.265*** | | 0.149*** | | 0.531*** | | 0.338*** |
| | | (0.015) | | (0.015) | | (0.138) | | (0.123) |
| IVSentIndex | | | 0.500*** | 0.459*** | | | 0.867*** | 0.762*** |
| | | | (0.015) | (0.015) | | | (0.136) | (0.136) |
| $R^2$ | 5% | 11% | 24% | 26% | 13% | 29% | 44% | 49% |
| F-stats | 38.0 | 76.7 | 204.7 | 196.3 | 2.5 | 4.1 | 8.0 | 8.5 |
| AIC | -29879 | -57219 | -57957 | -58058 | -430 | -850 | -872 | -878 |
| BIC | -29827 | -57162 | -57899 | -57994 | -405 | -825 | -847 | -850 |

## Table 10: Regression results: *Delta minus Gamma spread* controlled for investors' optimism

Panel A reports the regression results for Eq. (12) after controlling the *Delta minus Gamma spread* for investors' optimism. In Panel A, the dependent variable is the residual of one regression between *Delta minus Gamma spread* ($\delta$ - $\gamma$) and the Michigan Consumer Confidence index. The explanatory variables we specify are 1) the Baker and Wurgler (2007) sentiment measure (*SENT*), 2) the individual investor sentiment (*IISENT*), and 3) the explanatory variables used by Welch and Goyal (2008). In Panel B, the dependent variable is the residual of a regression between *Delta minus Gamma spread* ($\delta$ - $\gamma$) and the residuals of another regression between the Michigan Consumer Confidence index and a real-time proxy for economic conditions, implemented as in Beber et al. (2015). We report Newey-West adjusted standard errors in brackets. Asterisks ***, **, and * indicate significance at the one, five, and ten percent level, respectively.

| Panel A - Residual *DGspread* and Consumer Confidence | | | | | | | Panel B - Residual *DGspread* and Consumer Confidence/Fundamentals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Maturity* | 3m | 6m | 12m | 3m | 6m | 12m | 3m | 6m | 12m | 3m | 6m | 12m |
| *Intercept* | -0.036 | -0.337*** | -0.228*** | -0.065*** | -0.321*** | -0.400*** | -0.034 | -0.339*** | -0.232*** | -0.065*** | -0.320*** | -0.400*** |
| | (0.048) | (0.040) | (0.056) | (0.008) | (0.008) | (0.013) | (0.048) | (0.042) | (0.055) | (0.008) | (0.008) | (0.014) |
| *SENT* | 0.027** | 0.071*** | 0.022 | 0.027*** | 0.054*** | 0.002 | 0.020 | 0.064*** | 0.031* | 0.023** | 0.045*** | 0.005 |
| | (0.012) | (0.014) | (0.016) | (0.008) | (0.013) | (0.014) | (0.013) | (0.014) | (0.016) | (0.009) | (0.012) | (0.014) |
| *IISENT* | 0.066 | 0.055 | -0.010 | | | | 0.070 | 0.054 | -0.016 | | | |
| | (0.044) | (0.041) | (0.056) | | | | (0.044) | (0.041) | (0.056) | | | |
| *E12* | 0.000 | -0.113** | -0.178** | | | | 0.028 | -0.079* | -0.213** | | | |
| | (0.045) | (0.046) | (0.081) | | | | (0.046) | (0.044) | (0.079) | | | |
| *B/M* | -0.082 | 0.156 | -0.229 | | | | -0.135 | 0.126 | -0.149 | | | |
| | (0.193) | (0.163) | (0.235) | | | | (0.193) | (0.158) | (0.229) | | | |
| *NTIS* | -0.460 | -0.452 | 0.334 | | | | -0.247 | -0.316 | 0.017 | | | |
| | (0.367) | (0.304) | (0.618) | | | | (0.370) | (0.309) | (0.623) | | | |
| *TBL* | -6.933 | -2.308 | -22.114** | | | | -7.695 | -5.852 | -22.257*** | | | |
| | (6.997) | (5.967) | (8.244) | | | | (6.984) | (6.113) | (8.034) | | | |
| *INFL* | 1.343 | 4.824* | 6.181* | | | | 1.728 | 5.479** | 5.779* | | | |
| | (2.829) | (2.495) | (3.058) | | | | (2.811) | (2.475) | (3.079) | | | |
| *CORPR* | 0.302 | 0.287 | 0.179 | | | | 0.292 | 0.276 | 0.192 | | | |
| | (0.217) | (0.201) | (0.321) | | | | (0.217) | (0.200) | (0.313) | | | |
| *SVAR* | -0.855 | 5.520*** | 3.098 | | | | -1.375 | 5.032*** | 3.806 | | | |
| | (1.285) | (1.653) | (2.371) | | | | (1.270) | (1.607) | (2.451) | | | |
| *CSP* | -0.042 | 0.270* | 0.157 | | | | -0.030 | 0.309** | 0.152 | | | |
| | (0.136) | (0.148) | (0.249) | | | | (0.138) | (0.149) | (0.249) | | | |
| *R2* | 9% | 36% | 23% | 5% | 17% | 0% | 9% | 28% | 27% | 4% | 13% | 0% |
| *F-stats* | 1.7 | 9.6 | 5.1 | 9.4 | 37.8 | 0.0 | 1.7 | 6.7 | 6.2 | 6.7 | 27.0 | 0.2 |
| *AIC* | -361.4 | -402.0 | -269.0 | -326.1 | -186.0 | 34.1 | -361.1 | -396.4 | -271.0 | -326.1 | -186.0 | 34.1 |
| *BIC* | -326.1 | -366.8 | -233.8 | -320.0 | -179.9 | 40.3 | -325.8 | -361.2 | -235.8 | -320.0 | -179.9 | 40.3 |

## Table 11: Regression results: *Delta minus Gamma spread* controlled for investors' optimism and *IV-sentiment*

Panel A reports the regression results for Eq. (18) after controlling the *Delta minus Gamma spread* for investors' optimism. In Panel A, the dependent variable is the residual of one regression between *Delta minus Gamma spread* ($\delta$ - $\gamma$) and the Michigan Consumer Confidence index. In Panel B, the dependent variable is the residual of a regression between *Delta minus Gamma spread* ($\delta$ - $\gamma$) and the residuals of another regression between the Michigan Consumer Confidence index and a real-time proxy for economic conditions (i.e., a *Nowcasting* index), implemented as in Beber et al. (2015). The explanatory variables used in both regressions are the RND skewness, the RND kurtosis and the *IV-sentiment* factor at the three-month maturity. We report Newey-West adjusted standard errors in brackets. Asterisks ***, **, and * indicate significance at the one, five, and ten percent level, respectively.

| | DGspread | | | Residuals DGspread (DGspread-CC) | | | Residuals DGspread (DGspread-CCF) | | |
|---|---|---|---|---|---|---|---|---|---|
| *Maturity* | 3m | 6m | 12m | 3m | 6m | 12m | 3m | 6m | 12m |
| *Intercept* | -0.080*** | -0.370*** | -0.312*** | -0.056*** | -0.342*** | -0.355*** | -0.061*** | -0.338*** | -0.349*** |
| | (0.018) | (0.013) | (0.030) | (0.018) | (0.016) | (0.027) | (0.018) | (0.015) | (0.027) |
| *Skewness* | -0.035* | -0.008 | 0.059** | -0.028 | -0.001 | 0.055** | -0.029 | 0.000 | 0.056** |
| | (0.021) | (0.016) | (0.024) | (0.021) | (0.017) | (0.022) | (0.021) | (0.017) | (0.023) |
| *Kurtosis* | -0.006** | -0.001 | 0.002 | -0.006** | -0.001 | 0.003 | -0.006** | -0.001 | 0.002 |
| | (0.003) | (0.002) | (0.003) | (0.003) | (0.002) | (0.003) | (0.003) | (0.002) | (0.003) |
| *IV-sentiment 90-110* | -0.590*** | -1.173*** | -0.075 | -0.304*** | -0.873*** | -0.500*** | -0.281*** | -0.746*** | -0.514*** |
| | (0.080) | (0.096) | (0.180) | (0.088) | (0.113) | (0.166) | (0.086) | (0.112) | (0.170) |
| $R^2$ | 22% | 53% | 16% | 13% | 35% | 19% | 11% | 28% | 21% |
| *F-stats* | 16.8 | 67.1 | 11.1 | 9.2 | 32.1 | 13.9 | 7.1 | 22.7 | 15.8 |
| *AIC* | -383.3 | -453.8 | -248.8 | -384.6 | -413.9 | -274.1 | -378.3 | -409.6 | -271.7 |
| *BIC* | -370.5 | -440.9 | -236.0 | -371.8 | -401.1 | -261.3 | -365.5 | -396.8 | -258.9 |

## Table 12: Regression results: *Implied correlation* and *IV-sentiment*

The table below reports the regression results for Eq. (24). The explained variables in these regressions are the spread between normalized implied correlation (IC) provided by Buss et al. (2017) and our *IV-sentiment* measures. As IC correlation is provided in five different maturities, i.e., 30, 91, 182, 273 and 365, we have chosen the *IV-sentiment* data to roughly match them in the construction of our explained variable. Our explanatory variables are the risk-neutral skewness and kurtosis. Asterisks ***, **, and * indicate significance at the one, five, and ten percent level, respectively.

| Implied correlation | IC 30 | IC 91 | IC 182 | IC 273 | IC 365 |
|---|---|---|---|---|---|
| IV-Sentiment | 3m | | 6m | | 12m |
| *Intercept* | 0.770** | 0.654** | 0.534** | 0.447** | 0.527** |
| | (0.031) | (0.023) | (0.021) | (0.022) | (0.022) |
| *Skewness* | 0.002** | -0.066** | -0.143** | -0.185** | -0.132** |
| | (0.037) | (0.029) | (0.027) | (0.028) | (0.029) |
| *Kurtosis* | -0.067*** | -0.068*** | -0.071*** | -0.070*** | -0.068*** |
| | (0.005) | (0.004) | (0.004) | (0.004) | (0.004) |
| $R^2$ | 49% | 57% | 57% | 49% | 54% |
| *F-stats* | 1887.7 | 2666.8 | 2638.1 | 1917.2 | 2328.7 |
| *AIC* | 7062 | 4847 | 3981 | 4433 | 4356 |
| *BIC* | 7081 | 4866 | 4000 | 4452 | 4375 |

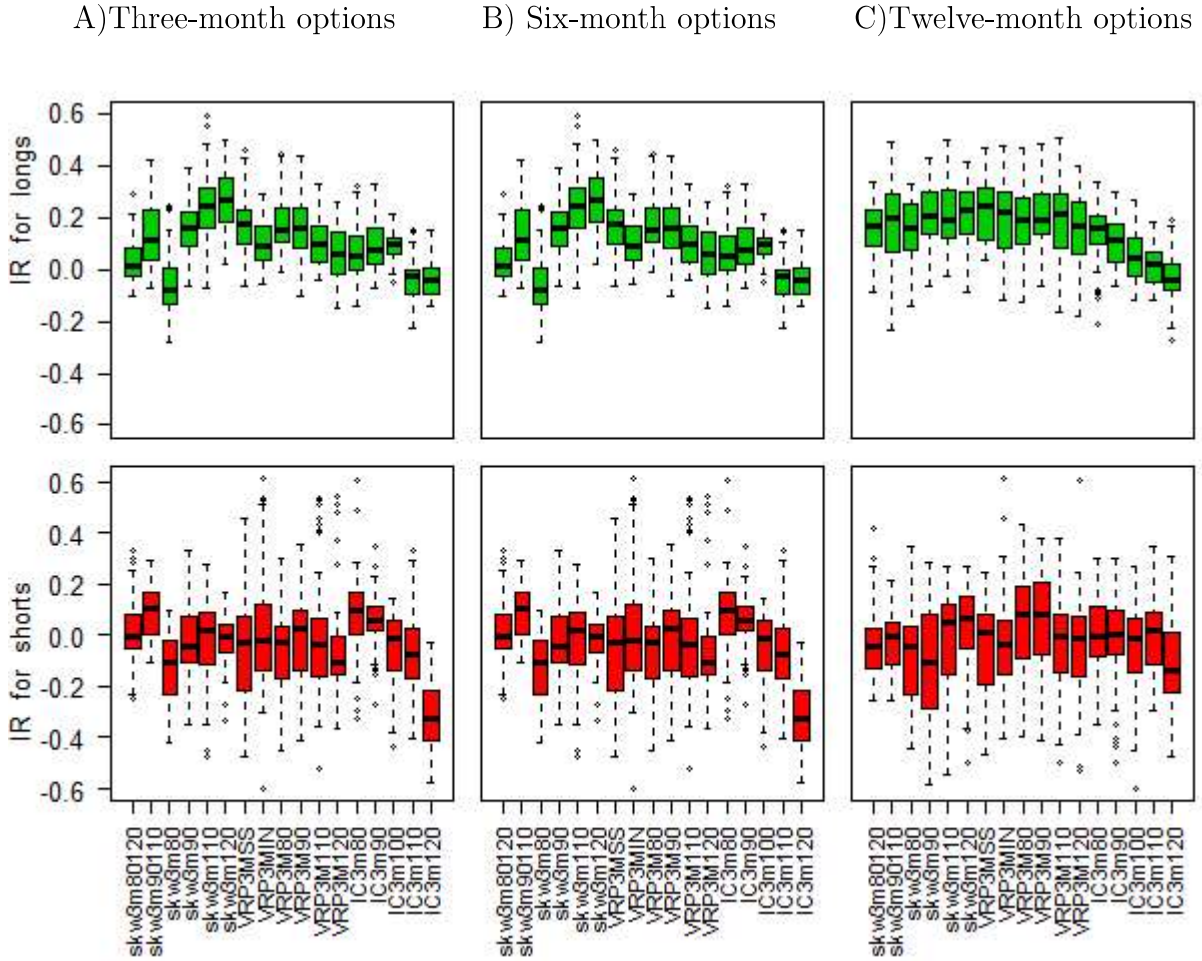


**Figure 6: Information ratio boxplot for long- and short-leg of IV-based strategies.** The boxplots depict the distribution of information ratios (IRs) obtained by the IV-based strategies tested, when different look-back periods and outer-threshold are used per factor-specific strategy. Boxplots on the top row (in green) refer to IRs produced by the long-leg of IV-based strategies, whereas the ones in the second row refer to the short-leg of the same strategies. Boxplot A depicts the distribution of IRs when the IV factor used is obtained from three-month options. Panels B and C depict the same information while using the IV factors obtained from six- and twelve-month options, respectively.

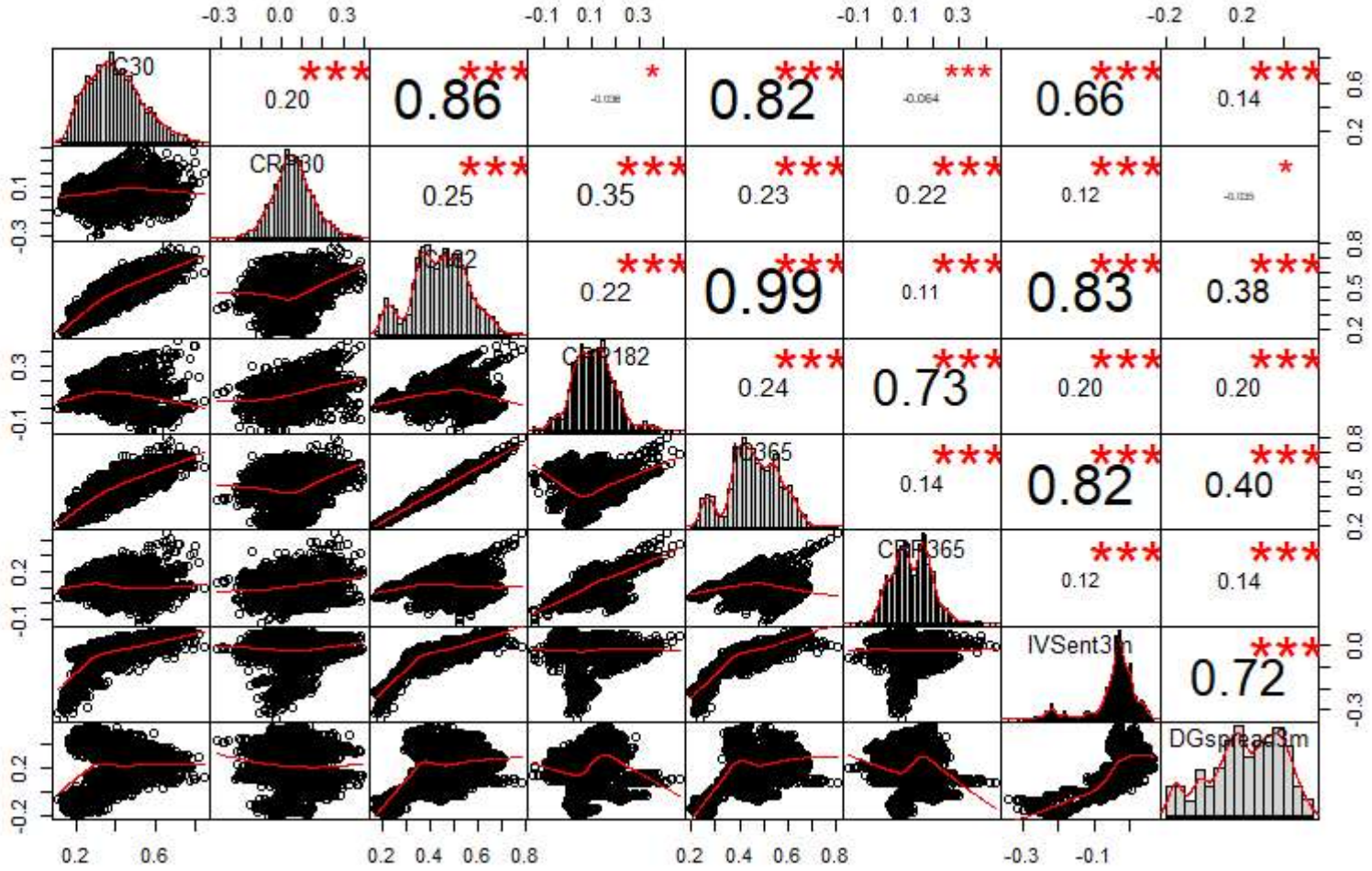


**Figure 7: Correlation matrix between the implied correlation (IC) and correlation risk premium (CRP) factor of Buss et al. (2017) with the *IV-sentiment* factor and *DGspread*.** The upper triangular part of the matrix above reports the correlation coefficient between pairs of IC and CRP factors with the *IV-sentiment* factor and the *DGspread*, both at the three-month maturity. The font size of coefficient reiterates its magnitude, whereas asterisks ***, **, and * indicate significance at the one, five, and ten percent level, respectively. In the diagonal, the histograms of factor returns are depicted. The lower triangular part of the matrix depicts scatter plots of the returns of the multiple pairs of factors.