Risk-Neutral Skewness and Commodity Futures Pricing

Ana-Maria Fuertes, Ph.D.
Bayes Business School, City, University of London, U.K.

Zhenya Liu, Ph.D.
Renmin University, China

Weiqing Tang, Ph.D.
Senior Quantitative Risk Management Associate, CME Group Inc., U.K.

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This paper investigates the predictive content of a risk-neutral skewness (RNSK) signal for the dynamics of commodity futures prices. A trading strategy that buys futures with positive RNSK and sells futures with negative RNSK generates a significant excess return, which suggests a positive RNSK-return nexus. The risk premia that can be extracted through the RNSK signal is more pronounced in the contango than backwardation phase. After accounting for traditional commodity futures predictors, the RNSK signal exhibits a relatively stable and prolonged predictive ability. The directional-learning hypothesis is able to rationalize the positive nexus in terms of arbitrage risks and illiquidity (positive RNSK) and overpricing (negative RNSK).

Introduction

Many studies have documented the pricing ability of skewness in equity markets. The commodity literature on this subject is much sparser, and the latest comprehensive empirical research is by Fernandez-Perez *et al*. (2018) who estimate Pearson skewness over past 1-year windows of daily returns and find a negative-return relation in the global futures market. However, there is no study on the option implied (risk-neutral) skewness pricing impact for the global futures market, and this paper seeks to fill this void.

This paper contributes to the commodity futures literature by formulating and empirically addressing various questions: Does risk-neutral skewness predict the futures return in the subsequent period? Is the risk-neutral skewness a more informative measure than the realized skewness measure (*i.e.*, Pearson skewness)? What is the potential mechanism underlying this option implied skewness pricing ability?

Deploying the methodology developed by Kozhan *et al*. (2013), the authors estimate at the weekly frequency a sequence of risk-neutral skewness signals for 22 commodities from agriculture, livestock, energy and metal sectors over a 10-year period. Then they construct a fully-collateralized long-short portfolio by buying (selling) commodities with the most positive (negative) risk-neutral skewness and rebalance it at a weekly frequency. This portfolio delivers an 13.18% annual return and an annualized alpha of 12.62% after taking into account the compensation for exposure to the traditional commodity risk factors (market long-only portfolio, term structure, momentum and hedging pressure) and the Pearson skewness. The authors show that the risk-neutral skewness is a more robust signal (less sensitive

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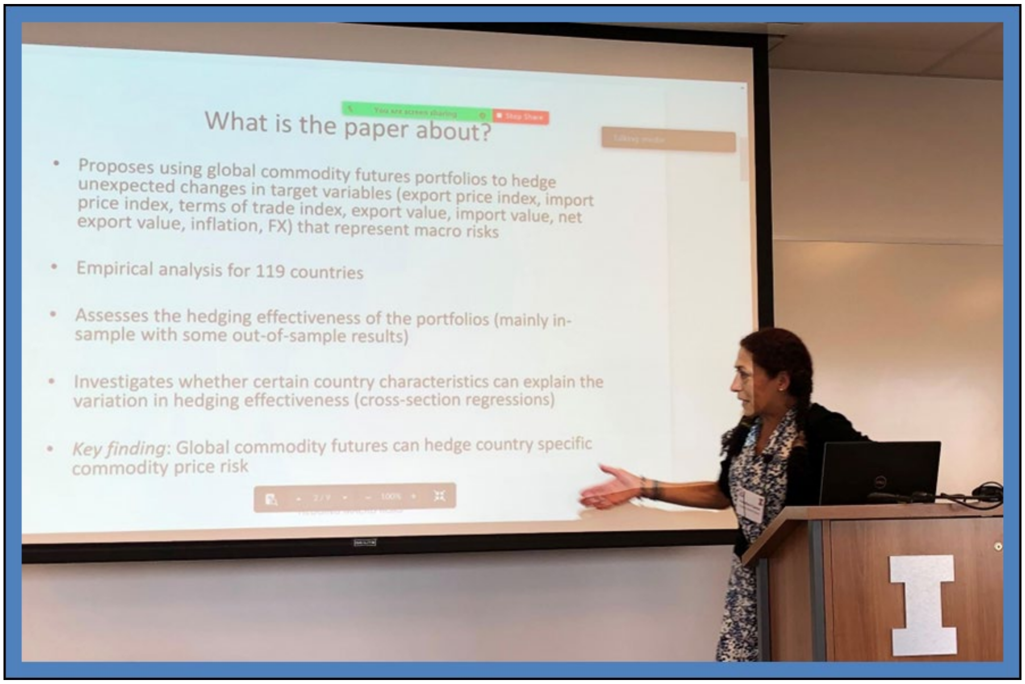
This digest article was contributed by Ana-Maria Fuertes, Ph.D., Professor in Finance and Econometrics at Bayes Business School, City, University of London (U.K.) and Associate Editor of the GCARD.

to sampling frequency and estimation window length) than the Pearson skewness and hence, it offers a more attractive portfolio cumulative return.



Professor Ana-Maria Fuertes of Bayes Business School, City, University of London, U.K., lecturing during the Commodities & Energy Markets Association (CEMA) conference at the University of Illinois' Illini Center in Chicago. This conference took place on June 21st and 22nd, 2022.

Using a double-sort portfolio analysis, the authors find that the positive return generated from buying more positively skewed commodity futures contracts is more pronounced precisely for those contracts with the highest (lowest) arbitrage risk/cost (liquidity) while the negative return generated from buying those negative skewed commodities is more pronounced for those contracts that are more overpriced.

The authors argue, under the directional-learning hypothesis by Kang and Park (2008), that investors with favorable predictions about the underlying futures contract will resort to the options market to buy more out-of-the-money (OTM) call options when the futures contract exhibits less liquidity and high idiosyncratic risk. When the futures contracts' liquidity is low, getting the best price is more challenging given a wider bid–ask spread market. Furthermore, trading activity via arbitrage, hedging, and speculation might be precarious for futures contracts with high idiosyncratic risk as intraday margin (collateral) calls with mark-to-market increased losses can force liquidation before convergence happens (Liu and Longstaff, 2004; Shleifer and Vishny, 1997). Investors will choose to purchase more OTM call options given all the associated risks above, driving RNSK to be more positive. Once the information is diffused to the underlying market, those assets will adjust their price to correct this belief.

Similarly, informed investors expecting negative movements in the futures market will resort to buying more OTM put options when the underlying assets are perceived to be overpriced. The present paper argues that there is a transfer of investors' risks (managing underlying inventory and hedging costs) to market-makers who consequentially require a premium on selling those OTM put options, yielding a more negative RNSK. Again, when information moves to the underlying market, the underlying price will react to correct the difference, generating a negative return. This is also compatible with the demand-based option pricing framework of Garleanu *et al*. (2009), leaving aside the short-selling constraint element.

Finally, in a cross-sectional analysis, the paper confirms that risk-neutral skewness is able systematically to price the futures contracts after controlling for a battery of extant commodity pricing factors.

Relevance of the Research Question

At a theoretical level, the significant relation between risk-neutral skewness and expected returns that the paper documents may instigate further research aimed at better understanding the price formation process in commodity futures markets. Traditional commodity pricing theories – the theory of storage of Kaldor (1939) and the hedging pressure hypothesis of Cootner (1960) – do not predict such relation.

A study of this nature on the relation between skewness and expected returns is relevant to academics and practitioners. At a practical level, the findings are potentially fruitful for commodity futures market participants as they suggest new ways of capturing risk premia through long-short portfolios formed according to a signal that is relatively unexploited in the commodities literature: risk-neutral skewness.

By contrast with the risk-neutral skewness, the Pearson skewness of commodity futures returns or realized skewness employed in Fernandez-Perez *et al*. (2018) is straightforward to estimate, but due to the properties of the returns, which are not necessarily realizations from an independent and identically distributed (IID) process, it can be sensitive to the choice of data frequency and estimation window length; for further discussion, see Neuberger (2012), Kim and White (2004), and Hansis *et al*. (2010). Through bootstrap simulation methods, Neuberger (2012) shows that realized skewness calculated from daily (monthly) data is not proportional to the realized skewness computed from monthly (yearly) data. Hansis *et al*. (2010) and Kim and White (2004) focus on the choice of estimation window length as the Pearson skewness requires; longer windows deliver more accurate Pearson skewness, but they may compromise the results by missing important short-term variation in the underlying return distribution. The aggregation property discussed by Neuberger (2012) implies that a low-frequency moment measure (*e.g.*, weekly RNSK) can be obtained in an unbiased way using high-frequency data (*e.g.*, daily options data).

Unlike the Pearson skewness, which is a backward-looking measure associated with the historical probability, the RNSK is a forward-looking measure associated with the risk-neutral probability – a probability of possible futures outcomes that have been adjusted for risk. The options market has been argued to carry valuable information for forecasting purposes as it reflects the market participants' expectations (see Bakshi *et al*., 1997; Bates, 1991; Black, 1975; Jackwerth and Rubinstein, 1996).

All in all, the present paper suggests that the RNSK of commodity futures returns represents a more informative skewness signal than the Pearson skewness for capturing risk premia and pricing purposes.

Data and Risk-Neutral Skewness Signal

The main data for the analysis are daily market observations for both futures and option contracts (price, trading volume, open interest, strike, time-to-maturity) from October 10, 2007 to March 1, 2016 from *Datastream* covering 22 commodity products within the agriculture, livestock, energy and metal sectors.

At each time t, for each commodity futures contract with a given expiration date T, the authors measure the risk-neutral skewness $RNSK_{t,T}$ signal of Kozhan *et al*. (2013) as

$$RNSK_{t,T} \equiv 3 \times \frac{V_{t,T}^{E} - V_{t,T}^{L}}{(V_{t,T}^{L})^{\frac{3}{2}}}$$

with

$$V_{t,T}^{L} = 2 \sum_{K_i \leq F_{t,T}} \frac{P_{t,T}(K_i)}{B_{t,T}K_i^2} \Delta I(K_i) + 2 \sum_{K_i > F_{t,T}} \frac{C_{t,T}(K_i)}{B_{t,T}K_i^2} \Delta I(K_i)$$

and

$$V_{t,T}^{E} = 2 \sum_{K_i \leq F_{t,T}} \frac{P_{t,T}(K_i)}{B_{t,T}K_iF_{t,T}} \Delta I(K_i) + 2 \sum_{K_i > F_{t,T}} \frac{C_{t,T}(K_i)}{B_{t,T}K_iF_{t,T}} \Delta I(K_i)$$

where $P_{t,T}(K_i)$ is the put option market price at time t, with multiple strike price levels K_i; similarly, $C_{t,T}(K_i)$ is the call option price; $F_{t,T}$ is the underlying futures price at time t with expiration date T; $B_{t,T}$ is the bond present value at time t with time-to-maturity T-t; $\Delta I(K_i)$ is the discrete increase among two adjacent strike prices. At the end of each sample week t, the commodity futures contracts are sorted according to their risk-neutral skewness measure *RNSK* and a fully collateralized long-short portfolio is formed by taking long positions in the top quintile with the highest RNSK and short positions in the quintile with the lowest RNSK; the constituent futures contracts are equally weighted. The portfolio is held for one week, when new RNSK signals are obtained and a new long-short portfolio is formed, and so forth.

Results

The fully-collateralized long-short RNSK portfolio generates an annualized 13.18% return with a Sharpe ratio of 1.39, which is significantly superior to the baseline Pearson skewness long-short portfolio yielding an annualized 1.63% return and Sharpe ratio 0.153 over the same period.

Next the authors regress the long-short RNSK returns on the long-only market portfolio, term structure, momentum and hedging pressure long-short portfolio returns that are the well-known proxies for commodity market backwardation and contango. In an additional test, the Pearson skewness based long-short portfolio returns are included as additional factor. The RNSK portfolio alpha is a significant 12.56% per annum (traditional risk factors) and 12.62% p.a. (traditional risk factors and Pearson skewness) suggesting that the returns accrued by the long-short RNSK portfolio are not compensation for exposure to existing commodity risk factors nor the Pearson-skewness risk.

Furthermore, scrutiny of the ranked commodity futures contracts according to the RNSK signal suggests that the commodities in the top (most positive) RNSK quintile exhibit the smaller or most negative values of the traditional signals – term structure, hedging pressure and momentum – signalling contango. This suggests an opposite pricing pattern whereby the RNSK premium is more available in the contango phase.

Finally, different from the findings in the equities' literature, the RNSK signal in the commodity futures market has a relatively stable and longer pricing predictability. The long–short portfolio sorted based on averaging signals of the RNSK over the window (up to 30 days) can yield a significant 14.6% return after controlling for traditional commodity baseline factors. Moreover, the RNSK at week *t* is proved to be able to predict futures return up to *t*+10 weeks, yielding at least an alpha of 6% p.a.

Using idiosyncratic volatility, Amihud's liquidity, and the maximum (max) daily futures return the over past month as proxies for arbitrage risk/cost, liquidity risk and overpricing, respectively (see Chordia *et al*., 2020; Cao and Han, 2013; Amihud *et al*., 1997; and Bali *et al*., 2011), a double-sort portfolio analysis is conducted. The findings suggest that the positive RNSK and return nexus in the global commodity futures market (with short-selling) is associated with liquidity, idiosyncratic risk, and overpricing. Specifically, the portfolio with the highest arbitrage risk within the top RNSK quantile yields a significant 35 basis points (bps) per week. The spread return between the most arbitrage-risk portfolio and the portfolio with the least arbitrage risk is a significant 22 bps per week. The most positive RNSK portfolio outperformance is led by the contracts with the lowest liquidity. In particular, the portfolio with the lowest liquidity quantile within the top (highest) RNSK quantile generates 38 bps per week. Moreover, within the top RNSK quantile, the spread return between a portfolio with the highest liquidity and a portfolio with the lowest liquidity yields a significant return, −22.4 bps per week. Finally, the double-sort approach reveals that the portfolio with the largest max daily futures return yields -21.8 bps per week. The spread return between the highest max past month-portfolio and the lowest max past month-portfolio is -32.9 bps per week.

Last but not least, the authors tests whether risk-neutral skewness can explain the cross-sectional return variation in the global futures market. There is a significant positive risk premium on average, which means that investors require compensation for being long futures contracts with more positive risk-neutral skewness.

Conclusions

This paper documents a significant positive relationship between risk-neutral skewness and returns in futures markets. Buying (selling) the commodities in the highest (lowest) risk-neutral skewness quintile simultaneously generates an annualized 13.18% return, which outperforms the return of the baseline Pearson skewness sorted long-short portfolio of Fernandez-Perez *et al*. (2018) with a 1.63% return over the same period. The risk-neutral skewness sorted long-short portfolio offers excess returns that are not compensation for traditional commodity risks, and is not encompassed by the Pearson skewness portfolio.

All in all, the positive relation documented in this paper between commodity futures risk-neutral skewness and returns are largely consistent with the demand-based option pricing theory of Garleanu *et al*. (2009). When the futures contracts become relatively illiquid and less attractive to arbitrage (speculation) activity, informed investors will purchase more OTM call options to maximize their profits. As that information is distributed to the underlying market, the futures price will increase to correct those beliefs implied from the options market. When the futures contracts are believed to be overpriced, to exploit the benefit of the potential price drop, informed investors will turn to the options market to obtain more OTM put options rather than to sell futures contracts to avoid potential risk. After the information moves to the underlying market, the commodity futures price will drop accordingly.

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Author Biographies

Ana-Maria Fuertes, Ph.D.
Bayes Business School, City, University of London, U.K.

Dr. Ana-Maria Fuertes is Professor of Finance and Econometrics at Bayes Business School (formerly Cass), City, University of London, which she joined in January 2001. Professor Fuertes has taught Statistics, Financial Econometrics, Forecasting, Time Series Econometrics, Operations Research, International Finance and Macroeconomics. She has acted as a consultant for Deutsche Bank and Barclays Capital. She has delivered bespoke postgraduate courses and has been awarded several teaching excellence prizes.

Her research interests are on commodity markets, empirical asset pricing, credit risk modelling and forecasting financial markets. Professor Fuertes' research has been published in leading journals such as *the Review of Finance, Journal of Banking and Finance*, *Journal of International Money and Finance*, *International Journal of Forecasting* and *Journal of Economic Dynamics and Control*. Her research has won academic prizes and has been featured in investors' blogs – *e.g*., Elitetrader, Amphitrading, Quantpedia, Yahoo Finance – and in policy blogs. She has served as Associate Editor of the *Journal of the Royal Statistical Society* (*Series A*), *Journal of Economic Behaviour and Organization* and *Journal of Computational Statistics and Data Analysis*. She is currently Associate Editor of the *International Journal of Forecasting* and the J.P. Morgan Center for Commodities' *Global Commodities Applied Research Digest* (*GCARD*).

Professor Fuertes holds a Ph.D. in International Finance, an M.Sc. in Control Engineering, and a B.Sc. in Industrial Engineering. Before joining academia, she worked as a Systems Analyst and Software Trainer for ESAI S.L. and as Cost-Analyst Programmer for INDALUX S.A. (est. 1950, a Spanish company recently acquired by the Dutch technology firm PHILIPS).

ZHENYA LIU, Ph.D.
Renmin University, China

Professor Zhenya Liu is a professor at the School of Finance, Renmin University of China, and a research associate of CERGAM, Aix-Marseille University, France. He obtained his Ph.D. in Economics at the Renmin University of China in 1994 and did his post-doc at Purdue University. His academic career has taken him across China, the U.K., and France. He was a Professor and Lead for Applied Quantitative Financial Research at Birmingham Business School, U.K. (2001-2017). His concern for bridging the gap between university and industry has led him to pursue multiple careers, such as a financial market practitioner (Director and Supervisor of the Board, J.P. Morgan Futures (China), 2007-2020).

He has published more than 20 books on the Chinese financial system and 60 papers in the *Journal of Econometrics*, *Econometric Theory*, *Econometric Reviews*, *Annals of Operations Research*, *International Journal of Forecasting*, *Review of Quantitative Finance and Accounting*, and *China Economic Review*.

Professor Liu is a leading expert in financial econometrics and quantitative investment, and he founded the Master and Ph.D. program in Quantitative Investment at the Renmin University of China. He currently focuses on stochastic optimal stopping time, change-point problems, statistical factor models, random matrix theory, and machine learning.

WEIQING TANG, Ph.D.
Senior Quantitative Risk Management Associate, CME Group Inc., U.K.

Dr. Weiqing Tang is a Senior Quantitative Risk Management Associate with Chicago Mercantile Exchange (CME) Group Inc. where he leads the Futures and Options related research team with a specific focus on the new generation of margin models. Dr. Tang holds a Ph.D. in Economics from the University of Birmingham, U.K. that dealt with the design of quantitative trading strategies, asset pricing, and functional statistical methods with application to financial markets.