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Is idiosyncratic asymmetry priced in commodity futures?

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Abstract

In this article, we use a recently introduced asymmetry measure, IE, to measure the idiosyncratic asymmetry of commodity futures returns and find that idiosyncratic asymmetry negatively and significantly predicts commodity futures returns cross sectionally. Furthermore, we find that a long–short trading strategy based on idiosyncratic asymmetry generates significant abnormal returns, which cannot be explained by traditional risk factors in commodity futures and persists up to 12 months. Moreover, idiosyncratic asymmetry appears to be a priced factor in commodity futures with significant risk premium. Finally, we confirm that IE is better at capturing the pricing effect of idiosyncratic asymmetry than the traditional skewness measure.

JEL CLASSIFICATION
G11, G12, G13

1 | INTRODUCTION

Idiosyncratic asymmetry and its asset pricing implications have received much attention in investment theory and practice. Tversky and Kahneman (1992), Mitton and Vorkink (2007), Barberis and Huang (2008), and Han et al. (2022) theoretically demonstrate that idiosyncratic asymmetry negatively affects the cross section of expected returns. Boyer et al. (2010), Annaert et al. (2013), Tavakoli Baghdadabad and Mallik (2018), and Bali et al. (2020), among others, have provided substantial evidence in stock markets to support this negative relation.

The traditional way to measure idiosyncratic asymmetry is the third-order moment coefficient of skewness. However, idiosyncratic skewness reflects the degree of asymmetry only to a certain point. To measure idiosyncratic asymmetry more efficiently, Jiang et al. (2020) propose a distribution-based measurement, IE, which is defined as the difference between upside and downside return probabilities. Jiang et al. (2020) show that IE can provide additional information beyond skewness. For a distribution with zero skewness, for example, it may still be asymmetrically distributed, which can be captured by IE. Moreover, following cumulative prospect theory, Jiang et al. (2020) derive a negative relation between IE and expected stock returns[1] and provide evidence that IE is more powerful in predicting the cross section of stock returns than skewness.[2]

In this article, we extend the work of Jiang et al. (2020) to commodity futures by examining whether idiosyncratic asymmetry measured by IE can also predict the cross-section of commodity futures returns. The commodity futures market differs from the stock market in several important aspects, which make it nontrivial to extend the findings in the stock market to the commodity futures market. First, it is dominated by institutional investors who are presumably more rational and less subject to behavioral biases. Second, although both long and short positions can be easily established in the commodity futures market with low trading costs, both sides are subject to mark-to-market daily. Third, commodity futures prices are greatly affected by supply and demand relations, in particular, seasonal variations between demand and supply. Fourth, perhaps because of the issues mentioned and other issues, commodity futures returns are even more volatile than stock returns, which makes it much harder to predict returns in the commodity futures markets.

Recently, Fernandez-Perez et al. (2018) document a negative relation between total asymmetry as measured by skewness and commodity futures returns. However, whether this negative relation is due to the idiosyncratic component or systematic component remains unknown. This is important because the aforementioned theoretical papers are based on idiosyncratic asymmetry instead of total asymmetry. Thus, it is necessary to investigate whether the negative relation between total asymmetry and future return is mainly driven by idiosyncratic asymmetry in the commodity futures market.

Additionally, Daskalaki et al. (2014) find that very few risk factors can be priced in commodity futures. They conduct a comprehensive study to investigate whether macro factors, equity-motivated tradable factors, commodity-specific factors, and latent factors from principal component analysis can be priced in commodity futures. They find that none of the factors are priced. Therefore, it is important to exam whether idiosyncratic asymmetry (IE) is a priced factor in commodity futures. If it is priced, it would make IE a rare candidate for any factor models aiming to explain commodity futures returns.

In sum, in this article we seek to answer the following questions: (1) Can idiosyncratic asymmetry (IE) predict the cross-section of commodity futures returns? (2) Is the total asymmetry pricing effect mainly driven by the idiosyncratic asymmetry (IE) in the commodity futures market? (3) Is idiosyncratic asymmetry a priced factor in the commodity futures market?

First, we use both Fama–MacBeth (1973) regressions and portfolio sorts to investigate the pricing effect of idiosyncratic asymmetry (IE) on a cross-section of commodity futures returns. We compare the results of IE with those of traditional measures and find that IE is better at capturing the negative relation between idiosyncratic asymmetry and expected returns. Based on the Fama–MacBeth (1973) regression results, we find that a 1 percentage point increase in idiosyncratic asymmetry (IE) reduces the expected returns of commodities by 2.63 basis points. This supports the prediction provided by the model of Jiang et al. (2020). It is also consistent with the theories of Mitton and Vorkink (2007), Barberis and Huang (2008), and Han et al. (2022). Our finding is robust when adding additional control variables for gambling preference, liquidity, and financial crisis, as well as using alternative methods to roll over the commodity futures contracts.

[1]An analytical proof is provided in Jiang et al. (2020).

[2]Evidence based on the US and Chinese stock markets are documented in Jiang et al. (2020) and Chen et al. (2022), respectively.

For the portfolio-sorting analysis, we form a monthly rebalanced long–short portfolio, which takes a long position in commodity futures with the lowest idiosyncratic asymmetry (IE) and a short position in commodity futures with the highest idiosyncratic asymmetry (IE). The return spread for this long–short portfolio is 0.56% per month, or 6.72% annually. It is economically and statistically significant, and the result is robust after considering the common risk factors in commodity futures. The sequential double-sorting results further confirm that the idiosyncratic asymmetry effect cannot be explained by the other control variables. Both the Fama–MacBeth (1973) regression and portfolio-sorting results show that commodity futures with higher idiosyncratic asymmetry (IE) tend to have lower expected returns. Furthermore, the negative and significant relation between idiosyncratic asymmetry (IE) and the commodity futures return persists up to 12 months, which suggests that idiosyncratic asymmetry (IE) could be a priced factor in the commodity futures markets.

Additionally, we investigate whether the asymmetry effect documented by Fernandez-Perez et al. (2018) is mainly driven by idiosyncratic asymmetry (IE). We find that the effect of idiosyncratic asymmetry (IE) is more important. By including both idiosyncratic asymmetry (IE) and the component of the total asymmetry (skewness) that is orthogonal to idiosyncratic asymmetry (IE) in the same regressions, we find that the coefficient of idiosyncratic asymmetry (IE) remains significant, whereas the coefficient of the orthogonal component becomes insignificant. This indicates that idiosyncratic asymmetry (IE) is the main driver of the asymmetry effect.

Finally, we show that idiosyncratic asymmetry (IE) is a priced factor in commodity futures. Using the Fama–MacBeth (1973) approach, that is, first running the daily time-series regressions for each commodity month-by-month to obtain the commodity betas, and then running the cross-sectional regression using the idiosyncratic asymmetry (IE) betas, we find that the price of the idiosyncratic asymmetry (IE) factor is 0.63% and highly significant. This finding is robust when adding liquidity, inflation, and investor sentiment as control variables.

We make several contributions to the literature. First, we extend the work of Jiang et al. (2020) to commodity futures. We show that IE can explain the cross-section of commodity futures returns. IE negatively and significantly predicts cross-sectional commodity futures returns. The tradable strategy based on IE in commodity futures can generate significant profits. We extend the analysis to show that IE is a priced factor in commodity futures, a finding beyond Jiang et al. (2020).

Second, we contribute to the literature on institutional investors and behavioral biases. Our finding that the pricing effect of idiosyncratic asymmetry exists not only in the stock market but also in the commodity futures market suggests that the same behavioral biases that lead to this pricing effect can also be observed among (institutional) investors in the commodity futures market. It is well documented that retail investors in stock markets are subject to behavioral biases that could lead to the idiosyncratic asymmetry pricing effect (Barberis & Huang, 2008; Han et al., 2022; Mitton & Vorkink, 2007). Despite the common belief that institutional investors are smart and more informed, recent studies have documented behavioral biases among institutional investors. Brown et al. (2018) show that some hedge fund managers are sensation seeking and prefer lottery-like stocks. Agarwal et al. (2022) show that mutual fund managers with small size, younger, and relatively poor past performance are more likely to prefer lottery-like stocks to attract more fund flows. Zhan et al. (2022) find that stock characteristics that are well known to predict stock returns can also predict the cross section of delta-hedged equity option returns, suggesting that even options traders may be subject to behavioral biases. Boyer and Vorkink (2014) show that option traders demand lottery-like options. Our article provides additional evidence that institutional investors in another derivative market, the commodity futures market, are also subject to behavioral biases.

Third, we shed new light on the negative relation between idiosyncratic asymmetry and cross section of returns. Fernandez-Perez et al. (2018) find evidence of a total skewness effect. In contrast, we show that the pricing effect of total asymmetry is subsumed by that of idiosyncratic asymmetry. Moreover, we show that idiosyncratic asymmetry measured by skewness is not significant in contrast to IE. This is because we use a distribution-based measure, which is better than skewness at capturing idiosyncratic asymmetry and has stronger predictive power than skewness. At least two factors contribute to its superior performance. First, IE captures more information than skewness as IE is distribution based whereas skewness is moment based. Second, IE is less noisy than skewness, which is sensitive to outliers, more so than the first two moments (Ghysels et al., 2016; Kim & White, 2004; Neuberger, 2012). In contrast, the distribution-based measure is robust to outliers.

Finally, we contribute to the literature of asset pricing in the commodity futures market by identifying a new priced factor. Daskalaki et al. (2014) find that none of the macro factors, equity-motivated tradable factors, commodity-specific factors, and latent factors from principal component analysis are significantly priced in the commodity futures market. However, we find that the long–short spread portfolio based on idiosyncratic asymmetry (IE) is a priced factor in the commodity futures market. It is robust even after controlling for additional risk factors. Additionally, except for idiosyncratic asymmetry (IE), we find that almost no risk factors have significant risk premia, which is consistent with Daskalaki et al. (2014).

2 | IDIOSYNCRATIC ASYMMETRY MEASURES

2.1 | IE

We employ the new measure of idiosyncratic asymmetry proposed by Jiang et al. (2020). Specifically, to assess upside (downside) asymmetry, we compute the excess tail probability following Jiang et al.'s (2020) IE_{φ}:

$$\text{IE}= \int_{0.5}^{+\infty} f(x)dx - \int_{-\infty}^{-0.5} f(x)dx = \int_{0.5}^{\infty}[f(x) - f(-x)]dx, \tag{1}$$

where the probabilities are evaluated at a half standard deviation away from the mean (zero), and x is the idiosyncratic return of commodity i, that is, the residual $\varepsilon_{i,d,t}$, in the following regression after standardized to have a unit variance, $R_{i,d,t} = \alpha_{i,t} + \beta_{i,t}R_{m,d,t} + \gamma_{i,t}R_{m,d,t}^2 + \varepsilon_{i,d,t}$, where $R_{i,d,t}$ is the daily return of commodity i on day d, and $R_{m,d,t}$ is the daily market return (i.e., daily return of S&P GSCI) on day d. Each month, we run the regression using 6 months of daily returns (from months $t - 5$ to t) to estimate the residuals. The first term in Equation (1) measures the cumulative chance of large gains, and the second term measures the cumulative chance of large losses. If IE is positive, the probability of large gains is higher than the probability of large losses, and thus the return is positively asymmetric.

IE has been shown to capture asymmetry better than skewness. By using IE, Jiang et al. (2020) detect more asymmetrical stocks in the US stock market. Moreoever, IE captures a higher percentage of asymmetry than skewness for both portfolios and individual stocks.

2.2 | ISKEW

We also employ the traditional measure of idiosyncratic asymmetry, denoted ISKEW, which is defined as the skewness of the daily residuals in the same daily regression presented earlier. Specifically, at each month t, we estimate ISKEW using Pearson's three-moment coefficient of skewness:

$$\text{ISKEW}_{i,t} = \frac{1/D\sum_{d=1}^{D}(\varepsilon_{i,d,t} - \overline{\mu}_{\varepsilon,i,t})^3}{\overline{\sigma}_{\varepsilon,i,t}^3}, \tag{2}$$

where $\varepsilon_{i,d,t}$ is the same daily residual of commodity i on day d defined earlier, and $\overline{\mu}_{\varepsilon,i,t}$ and $\overline{\sigma}_{\varepsilon,i,t}$ are its mean and standard deviation, respectively.

3 | DATA

3.1 | Commodity futures returns

Our main data are daily settlement prices from Bloomberg on front-end futures contracts for 27 commodities from distinct sectors. These sectors include energy (Brent crude oil, WTI crude oil, heating oil, natural gas), grains (corn, oats, soybean, soybean meal, soybean oil, wheat, rough rice), livestock (feeder cattle, hogs, live cattle), metals (aluminum, copper, gold, palladium, platinum, silver), and softs (cocoa, coffee, cotton, orange juice, sugar, milk, lumber).

To construct continuous time-series prices, we assume that for each commodity future, we always hold the first nearby contract (front-month contract) up to the expiration and then roll our position over to the second nearby contract and hold that contract up to maturity. The procedure is repeated to the next set of nearest and second-nearest contracts. As a robustness test, we consider an alternative method to roll over the contracts: We roll over to the next nearest contract at the end of the month before maturity.

Returns are computed as follows: $R_{i,t} = (p_{i,t} - p_{i,t-1})/p_{i,t-1}$, where $p_{i,t}$, $i = 1, \ldots, 27$ is the price of commodity i at time t. For daily returns, $p_{i,t-1}$ is the price of commodity i on the prior trading day. For monthly returns, $p_{i,t-1}$ is the price of commodity i at the end of the prior month.

3.2 | Idiosyncratic asymmetry

We use the daily returns of commodity i to compute the idiosyncratic asymmetry measures. Table 1 reports the values and t-statistics for IE, the traditional idiosyncratic asymmetry measure (ISKEW), and total asymmetry (SKEW) for all 27 commodity returns.

IE and ISKEW usually have the same signs, but the magnitude of IE is much smaller than that of ISKEW. However, the t-statistic of IE is larger, which implies that the standard error of IE is much smaller, suggesting that IE is much less noisy than ISKEW. In contrast, ISKEW is much close to total asymmetry (SKEW) in magnitude and t-statistic.

Across the different sectors of commodity futures, idiosyncratic asymmetry (IE and ISKEW) and total asymmetry (SKEW) can differ substantially. For example, the idiosyncratic and total asymmetries of grain and soft commodities are usually positive, whereas those of livestock are usually negative, and either positive and negative signs are found for energy and metals.

Table B1 in Appendix B reports the time-series averages of the pairwise correlations among the three asymmetry measures. SKEW and ISKEW are highly correlated with an average correlation of 0.8583. However, the correlations between IE and the other two measures are only about 0.4, suggesting that IE is different from the traditional measure of skewness and may capture additional information about asymmetry.

3.3 | Control variables

To control for the characteristics of commodity futures, we include volatility, trading volume, open interest, and past cumulative returns in the short term, medium term, and long term (Han et al., 2016). Specifically, they are the last-month return (R_{t-1}), 12-month momentum from $t - 12$ to $t - 2$ ($R_{t-12,t-2}$), and past 60-month cumulative return from $t - 60$ to $t - 2$ ($R_{t-60,t-2}$). These are the important characteristics of a commodity future that may influence its returns.

To control for systematic risks, we include four traditional risk factors: the market returns of the commodity futures market (MARKET), a term structure factor (TS), a momentum factor (MOM) following Bakshi et al. (2019),

TABLE 1 Descriptive statistics of asymmetry.

Commodity	IE		ISKEW		SKEW	
	Value	*t*-value	Value	*t*-value	Value	*t*-value
Energy						
Brent crude oil	0.0053	5.9768	0.1002	3.9567	−0.0174	−0.6508
WTI crude oil	0.0058	5.8620	0.1542	5.9192	−0.0017	−0.0559
Heating oil	0.0076	7.6168	0.0839	3.8444	0.0264	0.9017
Natural gas	0.0086	7.4136	0.1072	4.3987	0.1518	4.5975
Grains						
Corn	0.0035	3.4742	0.0784	3.7279	0.0837	4.0655
Oats	0.0060	6.7797	0.0778	3.0846	0.0857	3.2775
Soybean	−0.0045	−5.2238	−0.0435	−1.7864	−0.0533	−2.2010
Soybean meal	0.0128	11.8216	0.1454	6.3417	0.1530	6.2757
Soybean oil	0.0169	15.5515	0.2543	12.1252	0.2314	10.908
Wheat	0.0094	11.6182	0.1099	6.0163	0.1254	7.0796
Rough rice	0.0080	7.5884	0.1013	4.8496	0.1277	6.1287
Livestock						
Feeder cattle	−0.0017	−1.4569	−0.0234	−1.1771	−0.0399	−1.9514
Hogs	−0.0082	−9.0303	−0.0625	−5.0572	−0.0584	−4.9080
Live cattle	−0.0032	−3.2780	−0.0039	−0.3037	−0.0239	−1.8099
Metals						
Aluminum	0.0080	5.7550	0.0477	1.4718	0.0219	0.6257
Copper	0.0037	2.9745	0.0236	0.8765	0.0237	0.8731
Gold	−0.0040	−2.7080	−0.0018	−0.0418	−0.1212	−2.2802
Palladium	−0.0053	−4.0058	−0.0613	−3.1062	−0.0919	−4.6104
Platinum	−0.0044	−3.9569	−0.0570	−3.2300	−0.096	−5.4849
Silver	−0.0087	−7.4506	−0.1445	−4.4200	−0.2419	−6.8941
Softs						
Cocoa	0.0059	4.9373	0.0639	2.4765	0.0245	0.8843
Coffee	0.0044	3.2694	0.1252	4.1615	0.0972	3.0309
Cotton	0.0054	4.8987	0.0458	2.2374	0.0132	0.6519
Orange juice	0.0070	5.9118	0.4000	5.7673	0.4078	5.8473
Sugar	0.0037	2.7210	0.1284	1.7057	0.1053	1.3921
Milk	−0.0021	−1.0332	0.0603	0.7149	0.0233	0.2721
Lumber	0.0130	14.6128	0.1150	9.1425	0.1118	8.9465

Note: This table summarizes the asymmetry of the listed commodities. We include 27 commodities from distinct sectors: energy, grains, livestock, metals, and softs. IE is computed using Equation (1), and ISKEW and SKEW are Pearson's moment coefficients of idiosyncratic skewness and total skewness, respectively. The sample period is from January 1987 to May 2018.

and a hedging pressure factor (HP) following Basu and Miffre (2013). Whereas MARKET captures the overall commodity market risk based on the S&P GSCI index, TS, MOM, and HP are proxies for the risks associated with the backwardation/contango cycle of commodity futures markets.

Appendix A provides the variable definitions. Data for commodity futures are obtained from Bloomberg, and positions are obtained from the US Commodity Futures Trading Commission.

4 | EFFECT OF IDIOSYNCRATIC ASYMMETRY AT THE CHARACTERISTICS LEVEL

We examine the ability of idiosyncratic asymmetry to predict the cross-section of commodity futures returns. We investigate the effect of idiosyncratic asymmetry using the following Fama–MacBeth (1973) regression:

$$R_{i,t+1} = \lambda_{0,t} + \lambda_{1,t}\, asymmetry_{i,t} + \Lambda\, control_{i,t} + \varepsilon_{i,t+1}, \tag{3}$$

where $R_{i,t+1}$ is the monthly return of commodity i at time $t+1$, $asymmetry_{i,t}$ is the idiosyncratic asymmetry measured by either IE or ISKEW for commodity i estimated at time t, and $control_{i,t}$ is a set of control variables, including volatility, volume, open interest, R_{t-1}, $R_{t-12,t-2}$, and $R_{t-60,t-2}$. Because R_{t-1}, $R_{t-12,t-2}$, and $R_{t-60,t-2}$ represent the historical performance of commodity futures at the short term, medium term, and long term, respectively, we add them to Equation (3) either separately or together.

4.1 | Effect of idiosyncratic asymmetry using IE

Idiosyncratic asymmetry (IE) negatively affects the cross-section of commodity futures returns. Table 2 reports the results. In Column 1, the coefficient of IE is −0.0263 (t = −2.4221), significant at the 5% level. This indicates that an increase in idiosyncratic asymmetry (IE) reduces the expected returns of commodity futures. Even after controlling for other characteristics of commodity futures, the negative and significant effect remains. The commodity futures characteristics include volatility, volume, open interest, and historical returns in the short term (R_{t-1}), medium term ($R_{t-12,t-2}$), and long term ($R_{t-60,t-2}$). In Columns 2–5, the coefficients of IE are −0.0378 (t = −2.8629), −0.0230(t = −1.7600), −0.0281(t = −2.2427), and −0.0290(t = −1.9450), respectively, suggesting that the idiosyncratic asymmetry as measured by IE captures additional information about the cross section of returns beyond the common characteristics of commodity futures.

The negative effect of idiosyncratic asymmetry (IE) is consistent with several explanations in the literature. Based on cumulative prospect theory, Jiang et al. (2020) provide a representative–agent model and show that IE is negatively related to expected returns. For other related explanations, Mitton and Vorkink (2007) suggest that investors prefer a positively asymmetric asset, or a lottery-like asset if they have asymmetry or lottery preference, and subsequently overprice the asset, leading to lower expected returns. Barberis and Huang (2008) argue that investors overweight the probability of extreme events, such as extremely positive outcomes based on cumulative prospect theory. Thus, they are willing to pay more for an asset with a small probability of an extremely positive outcome. As a result, positively asymmetric assets become overpriced and have lower expected returns. The theory of Han et al. (2022) explains the effect through social transmission bias. The self-enhancing transmission bias of information senders leads to an attraction of asymmetry for information receivers because assets with higher returns are most likely to be discussed. Thus, this kind of asset tends to be overpriced and have lower expected returns. Although these theories are proposed for the stock market, results in Table 2 suggest that they likely hold in the commodity futures market as well. This finding implies that institutional investors may also have behavioral biases, consistent with evidence in other markets (Agarwal et al., 2022; Boyer & Vorkink, 2014; Brown et al., 2018).

TABLE 2 Characteristic level: Effect of idiosyncratic asymmetry on cross section of commodity futures returns.

	R_{t+1}				
	(1)	(2)	(3)	(4)	(5)
IE_t	−0.0263**	−0.0378***	−0.0230*	−0.0281**	−0.0290*
	(−2.4221)	(−2.8629)	(−1.7600)	(−2.2427)	(−1.9450)
$Volatility_t$		−0.0095	−0.0018	−0.0004	0.0000
		(−0.573)	(−0.1073)	(−0.0228)	(−0.0017)
$Volume_t$		−0.0064	−0.0042	−0.0014	−0.0108
		(−0.3264)	(−0.1981)	(−0.0661)	(−0.4956)
$Interest_t$		−0.0060	−0.0182	−0.0020	−0.0004
		(−0.2990)	(−0.8738)	(−0.1003)	(−0.0199)
R_{t-1}		0.0118			0.0239
		(0.3898)			(0.8228)
$R_{t-12,t-2t}$			0.0253		0.0346**
			(1.5453)		(2.1763)
$R_{t-60,t-2}$				−0.0058	−0.0269
				(−0.2640)	(−0.9749)
$Intercept_t$	0.0000	−0.0005	−0.0002	−0.0043	−0.0035
	(0.031)	(−0.0762)	(−0.0385)	(−0.7351)	(−0.4616)
Adj. R^2	0.02%	10.01%	10.10%	8.79%	17.51%

Note: This table reports the time-series average of the slope coefficients and their *t*-values from the Fama–MacBeth (1973) cross-sectional regressions of commodity futures returns on idiosyncratic asymmetry and control variables using Equation (3). The control variables include a set of characteristics of commodity futures. Newey–West *t*-statistics are reported in parentheses. Variables are defined in Appendix A. The sample period is January 1987 to May 2018.

*$p < 0.10$.

**$p < 0.05$.

***$p < 0.01$.

4.2 | Effect of idiosyncratic asymmetry using ISKEW

Considering the traditional measure of idiosyncratic asymmetry, we find that the effect is still negative but becomes marginally significant or insignificant. Table 3 reports the results. The coefficient of ISKEW is −0.0167(t = −1.4765) without any control variables. When adding the control variables, including volatility, volume, open interest, and R_{t-1}, the coefficient of ISKEW is still insignificant, −0.0220 (t= −1.6173). Only when we change the short-term historical performance to medium or long term, the coefficients of ISKEW become marginally significant, −0.0248(t = −1.9485) and −0.0224(t = −1.7403), respectively. After taking all these control variables into consideration, the coefficient of ISKEW remains insignificant, −0.0214 (t = −1.5964). This suggests that IE is better than ISKEW at capturing the pricing effect of idiosyncratic asymmetry. These results are in line with Jiang et al. (2020) who conclude that IE captures higher order asymmetry that goes beyond skewness. It suggests that when making investment decisions based on asymmetry, investors appear to consider IE rather than skewness, that is, the whole distribution rather than just the third moments. Statistically, IE is much less noisy than the skewness measure. Thus, IE is a better measure than traditional idiosyncratic asymmetry in capturing the asymmetry pricing effect.

TABLE 3 Using the traditional measure of idiosyncratic asymmetry.

	R_{t+1}				
	(1)	(2)	(3)	(4)	(5)
ISKEW_t	−0.0167	−0.0220	−0.0248*	−0.0224*	−0.0214
	(−1.4765)	(−1.6173)	(−1.9485)	(−1.7403)	(−1.5964)
$Volatility_t$		−0.0098	−0.015	−0.0032	−0.0069
		(−0.601)	(−0.8898)	(−0.2041)	(−0.3809)
$Volume_t$		−0.0086	−0.0154	−0.0069	−0.0194
		(−0.395)	(−0.7584)	(−0.3311)	(−0.9114)
$Interest_t$		−0.017	−0.0042	−0.0053	0.0039
		(−0.7931)	(−0.2013)	(−0.2535)	(0.1825)
R_{t-1}		0.0312*			0.0505***
		(1.9303)			(3.3049)
$R_{t-12,t-2t}$			−0.0019		0.0226
			(−0.0498)		(0.6059)
$R_{t-60,t-2}$				−0.002	−0.0201
				(−0.0882)	(−0.7795)
Intercept_t	0.0008	−0.001	−0.0036	−0.0037	−0.004
	(0.8934)	(−0.1918)	(−0.4575)	(−0.6371)	(−0.4615)
Adj. R^2	1.13%	11.01%	11.04%	10.08%	17.86%

Note: This table reports the time-series average of the slope coefficients and their *t*-values from the Fama-MacBeth cross-sectional regressions of the commodity futures returns on the traditional measure of the idiosyncratic asymmetry (*ISKEW*) and control variables. The control variables include a set of characteristics of commodity futures. Newey–West *t*-statistics are reported in parentheses. Variables are defined in Appendix A. The sample period is January 1987 to May 2018.

*$p < 0.10$.

***$p < 0.01$.

4.3 | Effect of idiosyncratic asymmetry versus total asymmetry

Because total asymmetry as measured by skewness has been shown to have a significant impact on commodity futures returns (Fernandez-Perez et al., 2018), we conduct further analysis to test whether the effect of the asymmetry is mainly driven by the effect of the idiosyncratic asymmetry. To this end, we include both idiosyncratic asymmetry (IE) and the residuals of the regression of total asymmetry on idiosyncratic asymmetry (IE):

$$R_{i,t+1} = \lambda_{0,t} + \lambda_{1,t}\text{IE}_{i,t} + \lambda_{2,t}\text{RES}_{i,t} + \Lambda\, control_{i,t} + \varepsilon_{i,t+1}, \tag{4}$$

where $\text{RES}_{i,t}$ represents the residuals of the regression of total asymmetry on idiosyncratic asymmetry for commodity i at time t.

Table 4 reports the results. We construct two residuals: one from time-series regressions and one from cross-sectional regressions. In Columns 1 and 2, where we use time-series residuals, the coefficient of IE is $-0.0211(t = -1.8398)$ or $-0.0375(t = -2.4971)$ without or with the control variables, whereas the coefficient of the residual is $-0.0184(t = -1.3682)$ or $-0.0154(t = -1.0520)$. The result shows that idiosyncratic asymmetry (IE) remains significant, whereas the component that is orthogonal to IE is insignificant. Similar results are

TABLE 4 Characteristic level: Idiosyncratic asymmetry versus total asymmetry.

	R_{t+1} (residuals of SKEW: time-series regression) (1)	(2)	R_{t+1} (residuals of SKEW: cross-sectional regression) (3)	(4)
IE_t	−0.0211*	−0.0375**	−0.0255**	−0.0348**
	(−1.8398)	(−2.4971)	(−2.3512)	(−2.4039)
RES_t	−0.0184	−0.0154	−0.0238*	−0.0168
	(−1.3682)	(−1.0520)	(−1.9581)	(−1.2475)
$Volatility_t$		−0.0037		−0.0052
		(−0.2059)		(−0.2842)
$Volume_t$		−0.0151		−0.0176
		(−0.6514)		(−0.7897)
$Interest_t$		−0.0005		0.0052
		(−0.0209)		(0.2385)
R_{t-1}		0.021		0.027
		(0.4903)		(0.6365)
$R_{t-12,t-2t}$		0.0477***		0.0474***
		(2.9291)		(2.9279)
$R_{t-60,t-2}$		−0.0348		−0.0368
		(−1.3229)		(−1.3384)
$\mathrm{Intercept}_t$	0.0012	−0.0019	0.0014	−0.0017
	(1.1944)	(−0.2049)	(1.4185)	(−0.18)
Adj. R^2	1.57%	18.73%	1.31%	18.29%

Note: This table reports the time-series average of the slope coefficients and their t-values from the Fama–MacBeth (1973) cross-sectional regressions of the commodity futures returns on both the idiosyncratic asymmetry (IE) and the residuals of the regressions of the total skewness on idiosyncratic asymmetry (IE). The control variables include a set of characteristics of commodity futures. Newey–West t-statistics are reported in parentheses. Variables are defined in Appendix A. The sample period is January 1987 to May 2018.

*$p < 0.10$.

***$p < 0.01$.

obtained in Columns 3 and 4, where we use the residuals from cross-sectional regressions. These results indicate that the pricing effect of the asymmetry in commodity futures is mainly driven by idiosyncratic asymmetry (IE).

4.4 | Robustness

We check the robustness of the idiosyncratic asymmetry (IE) effect. Because the preference for idiosyncratic asymmetry can reflect a gambling motivation (Barberis & Huang, 2008; Mitton & Vorkink, 2007), we first test robustness by adding a proxy for gambling preference as an additional control variable, such as MAX (Bali et al., 2011). We also consider MIN (Bali et al., 2011), COKURT (Dittmar, 2002), *liquidity* (Marshall et al., 2012;

Szymanowska et al., 2014),[3] and other control variables in the regressions. Appendix A provides definitions of the additional control variables.

The negative effect of idiosyncratic asymmetry (IE) is robust after adding MAX as a control variable. Column 1 in Table B2 presents the results. The coefficient of IE is −0.0342 (t = −2.2180), significant at the 5% level, and the coefficient of MAX is insignificant. This implies that the effect of idiosyncratic asymmetry may not be due to lottery preference. Similarly, the negative effect remains significant after controlling for MIN. Column 2 shows that the coefficient of IE is −0.0336 (t = −2.2798), suggesting that idiosyncratic asymmetry contains information beyond what is in MIN. In addition, after controlling for higher order risk, as measured by cokurtosis, the negative effect of idiosyncratic asymmetry (IE) remains, as shown in Column 3. The coefficient of IE is negative and significant, −0.0328 (t = −2.1740). This indicates that the effect is not challenged by cokurtosis. Furthermore, the negative effect of idiosyncratic asymmetry remains even after controlling for liquidity. Column 4 shows the results; the coefficient of IE is −0.0228 (t = −1.8443).

We also consider the impact of the financial crisis because it may greatly influence asset prices. To increase the power of the test, we use a dummy variable representing the financial crisis in the second step of the Fama–MacBeth (1973) regression instead of subdividing the samples. Table B3 reports the results. The negative effect of IE is robust after controlling for the financial crisis; the coefficient of IE remains negative and statistically significant with or without the control variables. Without controlling for the characteristics of the commodities, the coefficient of IE is −0.0261 (t = −2.3964). Even after adding the control variables, the coefficient is −0.0308 (t = −2.0275. Both are significant at the 5% level. Furthermore, the financial crisis does not have any significant effect on IE as the dummy always has insignificant coefficients.

In addition to the method we use, there are several alternative ways to roll over the commodity contracts (e.g., Gorton et al., 2012; Szymanowska, et al., 2014). Thus, we check robustness by using an alternative method to roll over the commodity contracts. That is, we roll over to the next nearest contract 1 month before maturity. We reestimate the regressions in Equation (3) with or without the control variables.

The negative effect of IE is robust when the alternative method is used to roll over the commodity contracts. Column 1 of Table B4 reports the results when rolling over to the next nearest contract at the end of the month before maturity. The coefficient of IE is −0.0328(t = −2.7589) without the control variables. After adding the control variables, the effect of idiosyncratic asymmetry remains negative and significant.

5 | IDIOSYNCRATIC ASYMMETRY TRADING STRATEGY

Given the significant relation between idiosyncratic asymmetry and expected returns in commodity futures, we construct long–short portfolios by sorting commodity futures according to their idiosyncratic asymmetry.

5.1 | Single-sorting

We rank the commodity futures (N = 27) by their idiosyncratic asymmetry at the end of each month t. Then we group them into three portfolios: Portfolio Q1, which contains the 30% of commodities with the lowest idiosyncratic asymmetry, up to portfolio Q3, which contains the 30% of commodities with the highest idiosyncratic asymmetry. Then we construct the monthly rebalanced long–short portfolio, which takes long positions in commodity futures with the most negative idiosyncratic asymmetry (Q1) and short positions in

[3]As mentioned in Marshall et al. (2012) and Szymanowska et al. (2014), liquidity plays an important role in commodity asset pricing. Therefore, we add *liquidity* as an additional control variable, which is defined as the dollar trading volume associated with the absolute return (Amihud et al., 1997).

commodity futures with the most positive idiosyncratic asymmetry (Q3). To further assess whether the profitability of the long–short portfolio based on idiosyncratic asymmetry is merely compensation for exposure to traditional commodity risk factors, we estimate the alpha of the long–short portfolio relative to a four-factor commodity pricing model:

$$r_{p,t} = \alpha_p + \theta_{p,\mathrm{EW}}\mathrm{MARKET} + \theta_{p,\mathrm{TS}}\mathrm{TS} + \theta_{p,\mathrm{MOM}}\mathrm{MOM} + \theta_{p,\mathrm{HP}}\mathrm{HP} + \upsilon_{p,t}, \tag{5}$$

where $r_{p,t}$ denotes the return of the long–short portfolio at month t. MARKET represents the market portfolio, TS represents the term structure factor, MOM represents the momentum factor, and HP represents the hedging pressure factor. These factors are the traditional risk factors in commodity futures markets.

Panel A of Table 5 reports the performance of IE-sorted tercile portfolios and the long–short portfolio. The mean return monotonically decreases from Q1 (negatively asymmetric) to Q3 (positively asymmetric). The mean return of Q1 is 0.97% (t = 2.9208) and that of Q3 is 0.41% (t = 1.7798). The trading strategy based on idiosyncratic asymmetry (IE) generates a significant profit. The spread of Q1–Q3 is 0.56% (t = 1.6655). In addition, the profitability of the long–short portfolio based on idiosyncratic asymmetry cannot be fully explained by traditional risk factors in commodity futures. Panel A also reports the alpha of the tercile portfolios and the spread portfolio from the four-factor commodity pricing model. The alpha of Q1 is 0.79% (t = 3.1080), that of Q3 is 0.09% (t = 0.5220), and that of the spread portfolio is 0.70% (t = 2.4890).

We further investigate the long-term predictive power of idiosyncratic asymmetry (IE). We hold the same portfolio formation, that is, ranking the commodities in cross-section according to their idiosyncratic asymmetry (IE) each month, but instead of calculating the returns in month t + 1, we take a further look at the monthly returns and alphas of the portfolios from months t + 2 to t + 12.

Panel B of Table 5 shows that the significant profits persist for several month into the future. During the 2nd month after portfolio formation, the return spread of the long–short portfolio Q1–Q3 is 0.93% (t = 2.7684). The significant spread persists until the 11th month after the portfolio formation month with a spread of 0.72% (t = 1.8897). Similar patterns are found for the alpha of the spread portfolios, which is significant up to the 12th month. Furthermore, the magnitude of the spread remains largely stable over the 12 months. These results suggest that the effect of idiosyncratic asymmetry (IE) is stable, and it is plausible that idiosyncratic asymmetry (IE) is a priced factor in the commodity futures. We continue to explore this issue in the next section.

In comparison, the traditional measure of idiosyncratic asymmetry shows weaker predictive power. Table 5 reports the performance of ISKEW-sorted portfolios and the long-term predictive power of ISKEW. Although the profit of the spread portfolio of ISKEW is similar to IE at time t + 1, it quickly disappears at time t + 4. At time t + 1, the excess return of the spread of Q1–Q3 is 0.59% (t = 1.6901). But the profit persists for only 3 months, and at time t + 4, the excess return of the spread of Q1–Q3 becomes insignificant. Similar to the excess return, the alpha of the spread portfolio persists for only 5 months.

5.2 | Double-sorting

We use the sequential double-sorting method to confirm that the idiosyncratic asymmetry effect is robust to the control variables. Specifically, at each month we first sort the commodity futures into two groups by one of the control variables. Within each group of the control variable, we then sort the commodity futures into two portfolios by idiosyncratic asymmetry (IE), creating 2 × 2 portfolios. Finally, we average across the two groups of the control variable to form two portfolios sorted by idiosyncratic asymmetry (IE) with a presumably similar level of the control variable.

Table 6 reports the results for the sequential double-sorting with the control variables. After averaging across the volatility portfolios, the return of the spread portfolio of idiosyncratic asymmetry (IE) is 0.53% (t = 2.4054), significant at the 5% level. After adjusting for the common commodity risk factors, the alpha of the spread portfolio remains significant, 0.59% (t = 2.9802), significant at the 1% level.

TABLE 5 Summary statistics for idiosyncratic-asymmetry-sorted portfolios.

	IE		ISKEW	
	Excess return	Adj. return (α)	Excess return	Adj. return (α)
Panel A: Portfolio at time t + 1				
Portfolio				
1 (lowest)	0.0097***	0.0079***	0.0101***	0.0081***
	(2.9208)	(3.1080)	(3.0046)	(3.2600)
2	0.0059***	0.0031**	0.0057***	0.0029
	(2.9796)	(2.0150)	(2.9781)	(1.5550)
3 (highest)	0.0041*	0.0009	0.0042*	0.0005
	(1.7798)	(0.5220)	(1.8141)	(0.3200)
Spread (Q1–Q3)	0.0056*	0.0070**	0.0059*	0.0075***
	(1.6655)	(2.4890)	(1.6901)	(2.7240)
Panel B: Portfolio from time t + 2 to t + 12				
Time				
t + 2	0.0093***	0.0088***	0.0061*	0.0079**
	(2.7684)	(2.8875)	(1.6928)	(2.5847)
t + 3	0.0064*	0.007**	0.006*	0.0073**
	(1.8705)	(2.303)	(1.6857)	(2.2844)
t + 4	0.0068**	0.0078***	0.0057	0.0065**
	(2.0389)	(2.6492)	(1.6083)	(2.0675)
t + 5	0.0072***	0.0075***	0.0054	0.0058*
	(3.2111)	(3.1527)	(1.5213)	(1.8009)
t + 6	0.0057**	0.0061**	0.0022	0.0021
	(2.4947)	(2.5009)	(0.9114)	(0.8145)
t + 7	0.0047**	0.0046*	0.0005	0.0002
	(2.0409)	(1.9465)	(0.14)	(0.0501)
t + 8	0.0056**	0.0052**	0.0028	0.0021
	(2.4633)	(2.2303)	(0.7289)	(0.6038)
t + 9	0.0091**	0.0095***	0.0059**	0.005**
	(2.5681)	(2.9393)	(2.4837)	(2.0133)
t + 10	0.0082**	0.0085**	0.0039*	0.0031
	(2.1638)	(2.479)	(1.6937)	(1.2722)
t + 11	0.0072*	0.0071**	0.0024	0.0011
	(1.8897)	(2.0805)	(0.6392)	(0.3415)

(Continues)

TABLE 5 (Continued)

	IE		ISKEW	
	Excess return	Adj. return (α)	Excess return	Adj. return (α)
t + 12	0.0063	0.0067*	0.0056	0.0052
	(1.6443)	(1.9009)	(1.5011)	(1.6028)

Note: This table summarizes the performance of the idiosyncratic asymmetry trading strategy. The commodities are sorted into terciles according to their idiosyncratic asymmetry (IE) and idiosyncratic skewness (ISKEW), and equal-weighted portfolios are constructed for each tercile. Panel B presents the long-term performance of the tercile portfolios. Portfolio Q1 contains the 30% most negative asymmetric commodities, and Q3 contains the 30% most positive asymmetric commodities. The portfolios are rebalanced every month. The spread portfolio (Q1–Q3) longs Q1 and shorts Q3. We report the average monthly commodity returns for each portfolio, and the alpha from regressing the returns on the traditional commodity risk factors MARKET, TS, MOM, and HP using Equation (5). Newey–West t-statistics are reported in parentheses. Variables are defined in Appendix A. The sample period is January 1987 to May 2018.

*$p < 0.10$.

**$p < 0.05$.

***$p < 0.01$.

Similar results are found after controlling for volume, open interest, R_{t-1}, $R_{t-12,t-2}$, $R_{t-60,t-2}$, MAX, MIN, COKURT, and *liquidity*, respectively. These results indicate that the IE effect cannot be explained by other control variables, which is consistent with the results reported in Section 4.

5.3 | Idiosyncratic asymmetry versus total asymmetry

We use a portfolio-sorting approach to test whether idiosyncratic asymmetry (IE) mainly drives the asymmetry effect in commodity futures. As in Section 4, we use the residuals of the regressions of total asymmetry on idiosyncratic asymmetry (IE) to conduct the portfolio-sorting analysis. We sort the commodity futures into three portfolios by the residuals.

Using portfolio sorts, Table 7 confirms that idiosyncratic asymmetry (IE) mainly drives the asymmetry effect in commodity futures. In Table 7, the mean return of the portfolio with the lowest residual is 0.68% (t = 2.9879) and that of the portfolio with the highest residual is 0.39% (t = 1.8323). However, the mean return of the spread portfolio (Low–High) is insignificant, 0.28% (t = 1.1744). Similar results are obtained when we sort the commodities by the residuals of the cross-sectional regression of the total asymmetry on idiosyncratic asymmetry (IE). These results imply that idiosyncratic asymmetry is the main component of the asymmetry effect in commodity futures, consistent with the findings in Section 4.

6 | IDIOSYNCRATIC ASYMMETRY FACTOR

We investigate whether idiosyncratic asymmetry (IE) is a priced factor. First, we estimate the time-series regressions month-by-month (daily data in one month) for each commodity to obtain the commodity monthly betas for idiosyncratic asymmetry (IE) and other risk factors:

$$r_{i,t,d} = \alpha_{i,t} + \beta_{i,t}^{F} F_{t,d} + \upsilon_{i,t,d}, \tag{6}$$

TABLE 6 Double-sorted portfolio returns.

	Q1	Q2	Q1–Q2	Adj. return (α)
Volatility	0.0089***	0.0036*	0.0053**	0.0059***
	(3.758)	(1.8389)	(2.4054)	(2.9802)
Volume	0.0068***	0.0021	0.0048***	0.0047***
	(3.6962)	(0.9937)	(2.7375)	(2.6609)
Open interest	0.007***	0.0016	0.0054***	0.0053**
	(3.4916)	(0.6923)	(2.6859)	(2.5506)
$R_{t-12,t-2}$	0.0088***	0.004**	0.0048**	0.0055***
	(3.7332)	(2.0223)	(2.1722)	(2.7822)
R_{t-1}	0.0081***	0.0048**	0.0033	0.004*
	(3.4112)	(2.3713)	(1.4261)	(1.9327)
$R_{t-60,t-2}$	0.0095***	0.0033*	0.0061***	0.0071***
	(3.8003)	(1.6877)	(2.6414)	(3.5426)
MAX	0.0089***	0.0038*	0.0052**	0.0058***
	(3.7944)	(1.9428)	(2.4139)	(3.0683)
MIN	0.0094***	0.0036*	0.0058**	0.0063***
	(3.7699)	(1.7879)	(2.4566)	(3.0446)
COKURT	0.01***	0.0026	0.0073***	0.0079***
	(3.9186)	(1.361)	(3.1287)	(3.926)
liquidity	0.0072***	0.0017	0.0055***	0.0056***
	(3.8143)	(0.8258)	(3.0278)	(3.0209)

Note: This table presents sequential double-sorted portfolio returns sorted by one of the control variables and idiosyncratic asymmetry (IE). At each month, we first sort the commodities into two groups by each control variable. Within each group, we sort the commodities into two portfolios by idiosyncratic asymmetry, creating 2 × 2 portfolios. Finally, for each idiosyncratic asymmetry group (Q1 and Q2), we average across the two groups of the control variable. The spread portfolio (Q1–Q2) longs Q1 and shorts Q2. For each portfolio, we report the average return and the alpha from regressing the returns on the traditional commodity risk factors MARKET, TS, MOM, and HP using Equation (5). Newey–West *t*-statistics are reported in parentheses. Variables are defined in Appendix A. The sample period is January 1987 to May 2018.

*$p < 0.10$.

**$p < 0.05$.

***$p < 0.01$.

where $r_{i,t,d}$ is the daily commodity return at date d for commodity i in month t, and $d = 1, \ldots, D$, where D denotes the number of trading days in month t. $F_{t,d}$ represents the daily returns on the spread portfolio of idiosyncratic asymmetry (IE) or other traditional risk factors (MARKET, TS, MOM, HP) in month t.

Then we estimate the cross-sectional regression month by month:

$$r_{i,t+1} = \lambda_0 + \lambda_{\mathrm{IE},t}\hat{\beta}_{i,t}^{\mathrm{IE}} + \Lambda_{F,t}\hat{\beta}_{i,t}^{F} + e_{i,t+1}, \tag{7}$$

where $\hat{\beta}_{i,t}^{\mathrm{IE}}$ represents the factor loading of the idiosyncratic asymmetry (IE) factor for commodity i at month t, and $\hat{\beta}_{i,t}^{F}$ represents the factor loading of all other risk factors (MARKET, TS, MOM, HP) for commodity i at month t. We report the average $\lambda_{\mathrm{IE},t}$ and $\Lambda_{F,t}$ of the pass-two cross-sectional regression in Equation (7).

TABLE 7 Single-sorted portfolio returns by residuals of the total skewness.

SKEW Low	SKEW 2	SKEW High	Low–High
Panel A: Residuals of time-series regressions			
0.0068***	0.0084***	0.0039*	0.0028
(2.9879)	(2.7467)	(1.8323)	(1.1744)
Panel B: Residuals of cross-sectional regressions			
0.0067***	0.0091***	0.0032	0.0036
(3.0352)	(2.9898)	(1.4089)	(1.4995)

Note: This table reports single-sorted portfolio returns by the total skewness residuals. The commodities are sorted into terciles, and an equal-weighted portfolio is constructed for each tercile. Portfolio SKEW Low contains the 30% commodities with the most negative residual skewness, and SKEW High contains the 30% commodities with the most positive residual skewness. Residual skewness is estimated using time-series regressions (Panel A) or cross-sectional regressions (Panel B). The portfolios are rebalanced every month. The spread portfolio (Low–High) longs SKEW Low and shorts SKEW High. Newey–West *t*-statistics are reported in parentheses. The sample period is January 1987 to May 2018.

***$p < 0.01$.

6.1 | Cross-sectional asset pricing tests

Table 8 presents the results of the two-pass cross-sectional regressions, which show that the idiosyncratic asymmetry (IE) factor can explain the cross-section of commodity futures returns. When regressing commodity returns on the IE beta alone, the price of the asymmetry factor ($\lambda_{IE,t}$) is 0.0063 (t = 2.9479), significant at the 1% level. This indicates that investors require compensation for exposure to commodity futures with a lower level of idiosyncratic asymmetry (i.e., a more negative idiosyncratic asymmetry). After controlling for the traditional risk factors separately or jointly, the price of IE remains significant. None of the traditional risk factors except for hedging pressure (HP) have significant risk premia.

6.2 | Robustness

To examine the robustness of the performance of the idiosyncratic asymmetry (IE) factor, we include additional risk factors in commodity futures in the Fama–MacBeth (1973) two-pass regressions. First, following Marshall et al. (2012), Szymanowska et al. (2014), and Amihud et al. (1997), we include a liquidity beta based on the Amihud measure. Second, considering the influence of the macroeconomy, we include an inflation beta estimated by regressing the monthly commodity futures returns in the prior 60 months on changes in the 1-month US Consumer Price Index. Third, to test whether investor sentiment alters the price of the idiosyncratic asymmetry factor,[4] we employ a sentiment beta as the slope coefficient in the regression of the prior 12-month commodity futures returns on the sentiment index (Baker & Wurgler, 2006).

Table B5 reports the results. The performance of the idiosyncratic asymmetry (IE) factor is robust after controlling for the alternative risk factors. In Column 1, after considering the liquidity risk factor, the price of IE remains significant at the 1% level, 0.0151(t = 3.0679). After controlling for the inflation factor, the price of IE is

[4]Many studies document that some anomalies or factors may be affected by investor sentiment. For example, Stambaugh et al. (2012) find that some anomaly effects are varied because of investor sentiment. Bi and Zhu (2020) find that the value-at-risk effect is much stronger during high-sentiment periods.

TABLE 8 Cross-sectional pricing ability of the idiosyncratic asymmetry factor.

	R_{t+1}					
	(1)	(2)	(3)	(4)	(5)	(6)
β_t^{IE}	0.0063***	0.0094***	0.0061***	0.0069**	0.0045*	0.0104**
	(2.9479)	(3.8217)	(2.6561)	(2.4231)	(1.7985)	(2.0149)
β_t^{MARKET}		0.0051				−0.0006
		(1.3872)				(−0.0675)
β_t^{TS}			0.0005			0.0219
			(0.1853)			(0.7979)
β_t^{HP}				0.0147**		0.0392*
				(2.4291)		(1.7087)
β_t^{MOM}					−0.0013	0.0162
					(−0.4389)	(0.8595)
Intercept_t	0.006***	0.0053***	0.0066***	0.0056***	0.006***	0.0056***
	(3.4555)	(3.5379)	(3.9895)	(3.4962)	(3.8719)	(3.589)
Adj. R^2	5.94%	13.72%	13.03%	11.97%	12.79%	25.04%

Note: This table reports the time-series average of the slope coefficients and their *t*-values from the two-pass Fama–MacBeth (1973) cross-sectional regressions of the commodity futures returns on the factor loadings using Equation (7). Newey–West *t*-statistics are reported in parentheses. Variables are defined in Appendix A. The sample period is January 1987 to May 2018.

*$p < 0.10$.

**$p < 0.05$.

***$p < 0.01$.

0.0096 (t = 2.8841), significant at the 1% level. After considering investors' sentiment, the price of IE is 0.0132 (significant at the 5% level). Even after adding all the risk factors together, the price of IE remains significant, 0.0155 (t = 3.3578). The information content in idiosyncratic asymmetry is not a proxy for alternative economic and financial risk factors.

7 | CONCLUSION

In this article, we investigate the ability of idiosyncratic asymmetry (IE) to explain the cross-section of commodity futures returns at both the characteristics and factor levels. We first test the pricing effect of idiosyncratic asymmetry on the cross-section of commodity futures returns at the characteristics level using both the Fama–MacBeth (1973) regression and portfolio sorting analysis. We find that idiosyncratic asymmetry negatively and significantly predicts commodity futures returns, which is consistent with recent empirical findings in the US and Chinese stock markets, and it supports the model prediction presented in Jiang et al. (2020). Furthermore, the new distribution-based asymmetric measure, IE, is better at capturing the effect of idiosyncratic asymmetry than the traditional measure. In addition, we find that the asymmetry effect documented in the literature is mainly driven by idiosyncratic asymmetry (IE) in the commodity futures market. Moreover, we show that idiosyncratic asymmetry (IE) is a priced factor in commodity futures. It has a significant risk premium. The result is robust when adding other traditional risk factors (MARKET, TS, MOM, HP) and risk factors such as liquidity, inflation, and investor sentiment.

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APPENDIX A: VARIABLE DEFINITIONS

Variable	Definition
SKEW	Total asymmetry (skewness) is defined by the following equation: $$\text{SKEW}_{i,t} = \frac{1/D\sum_{d=1}^{D}(R_{i,d,t} - \hat{\mu}_{i,t})^3}{\hat{\sigma}_{i,t}^3}$$ It is obtained at each month-end t using daily return history of commodity i over the preceding $t - 5$ to t window
ISKEW	Idiosyncratic asymmetry (skewness) of commodity i in month t is computed using the daily residuals in the equation $R_{i,d} = \alpha_i + \beta_i R_{m,d} + \gamma_i R_{m,d}^2 + \varepsilon_{i,d}$ from months $t - 5$ to t
IE	Difference between the upside and downside return probabilities using Equation (1)
RES	Residuals of the regression of total asymmetry on idiosyncratic asymmetry for commodity i at time t
Volatility	Standard deviation of daily returns of commodity i in month t
Volume	Number of contracts of commodity i traded in month t
Open interest	Total number outstanding of commodity contracts that have not been settled
$R_{t-12,t-2}$	Momentum is past 6-month average returns from $t - 2$ to $t - 6$
R_{t-1}	Prior-month r is the last-month return
$R_{t-60,t-2}$	Prior 60-month r is the past 60-month cumulative return from $t - 2$ to $t - 60$
MAX	Following Bali et al. (2011), MAX is extreme positive returns in month t, which is defined by the following equation: $$\text{MAX}_{i,t} = \max(R_{i,d})$$

(Continues)

Variable	Definition
MIN	Following Bali et al. (2011), MIN is extreme negative returns in month t, which is defined by the following equation: $$\text{MIN}_{i,t} = -\min(R_{i,d})$$
COKURT	Following Dittmar (2002), COKURT measures the common sensitivity of the variable to the extreme returns and is defined by the following equation: $$\text{COKURT}_{i,t} = \frac{1/D_t \sum_{d=1}^{D_t} R_{i,d} R_{m,d}^3}{\sqrt{1/D_t \sum_{d=1}^{D_t} R_{i,d}^2}\left(1/D_t \sum_{d=1}^{D_t} R_{m,d}^2\right)^{3/2}}$$
Liquidity	Following Amihud et al. (1997), liquidity is the dollar trading volume associated with the absolute return using the following equation: $$liquidity_{i,t} = \frac{1}{D}\sum\frac{\$volume_{i,d}}{\lvert r_{i,d}\rvert}$$
Financial crisis	Dummy variable that equals 1 between December 2007 and June 2009, and 0 otherwise
MARKET	Factor of market return (S&P GSCI)
TS	Factor of roll yield. Roll yield is measured as the daily difference in logarithmic prices of the front-end and second-nearest contracts. The TS portfolio buys (and simultaneously sells) the 30% tercile with highest (lowest) average roll yield over the previous 12 months
HP	Factor of the hedgers' and speculators' hedging pressure. Hedging pressure of hedgers (speculators) is measured as the long position of hedgers (speculators) divided by the total positions of hedgers (speculators). The HP portfolio buys (and simultaneously sells) the 30% tercile with highest (lowest) average total hedging pressure over the previous 12 months
MOM	Factor of momentum. The MOM portfolio buys (and simultaneously sells) the 30% tercile with highest (lowest) average momentum over the previous 12 months
Inflation	Changes in 1-month US Consumer Price Index
Sentiment	Sentiment indicator introduced by Baker and Wurgler (2006)

APPENDIX B

TABLE B1 Cross-sectional correlation between total skewness and idiosyncratic skewness.

	1	2	3
1. SKEW	1.0000		
2. ISKEW	0.8583	1.0000	
3. IE	0.4008	0.4123	1.0000

Note: This table reports the time-series average of the pairwise cross-sectional correlation between total skewness (SKEW) and idiosyncratic skewness (ISKEW and IE). Variables are defined in Appendix A.

TABLE B2 Robustness check at the characteristic level: Additional control variables.

	R_{t+1}			
	(1)	(2)	(3)	(4)
IE_t	−0.0342**	−0.0336**	−0.0328**	−0.0288*
	(−2.2180)	(−2.2798)	(−2.1740)	(−1.8443)
MAX_t	0.0242			
	(0.6412)			
MIN_t		0.0258		
		(0.7087)		
$COKURT_t$			−0.0063	
			(−0.3494)	
$Liquidity_t$				0.0140
				(0.7166)
$Volatility_t$	−0.0154	−0.0071	−0.0033	−0.0233
	(−0.665)	(−0.3102)	(−0.1494)	(−0.9531)
$Volume_t$	−0.003	−0.0128	−0.0046	−0.0074
	(−0.133)	(−0.5702)	(−0.2242)	(−0.3488)
$Interest_t$	0.0495*	0.034	0.0287	0.0249
	(1.6724)	(1.3195)	(0.5873)	(0.8002)
$R_{t-12,t-2}$	0.0393**	0.0368**	0.0449**	0.0412**
	(2.167)	(2.2011)	(2.509)	(2.491)
R_{t-1}	−0.0189	−0.0255	−0.0099	−0.0215
	(−0.6855)	(−0.9324)	(−0.3719)	(−0.7406)
$R_{t-60,t-2}$	−0.0156	−0.0332	0.0004	0.0283
	(−0.4294)	(−0.886)	(0.0189)	(1.6426)
$Intercept_t$	0.0005	−0.0074	0.0021	−0.0036
	(0.067)	(−0.9612)	(0.1978)	(−0.4545)
Ad. R^2	20.09%	19.83%	21.99%	17.81%

Note: This table presents the results of the robustness tests of the idiosyncratic asymmetry effect after controlling for MAX (Bali et al., 2011), MIN (Bali et al., 2011), COKURT (Dittmar, 2002), and *liquidity* (Amihud et al., 1997). It reports the time-series average of the slope coefficients and their *t*-values from the Fama–MacBeth (1973) cross-sectional regressions of the commodity futures returns on idiosyncratic asymmetry and control variables. Newey–West *t*-statistics are reported in parentheses. Variables are defined in Appendix A. The sample period is January 1987 to May 2018.

*$p < 0.10$.

**$p < 0.05$.

TABLE B3 Robustness check at the characteristic level: Financial crisis.

	R_{t+1}		R_{t+1}	
	$\gamma_{0,k}$	$\gamma_{1,k}$	$\gamma_{0,k}$	$\gamma_{1,k}$
IE_t	−0.0261**	−0.0057	−0.0308**	0.0345
	(−2.3964)	(−0.0750)	(−2.0275)	(0.4600)
$Volatility_t$			0.0011	−0.0229
			(0.0600)	(−0.4485)
$Volume_t$			−0.0080	−0.0500
			(−0.355)	(−0.7384)
$Interest_t$			−0.0022	0.0283
			(−0.1005)	(0.3243)
$R_{t-12,t-2}$			0.0283	−0.0864
			(0.9305)	(−1.241)
R_{t-1}			0.0305*	0.0817
			(1.8428)	(1.5814)
$R_{t-60,t-2}$			−0.0329	0.1196
			(−1.1630)	(0.9787)
$Intercept_t$	0.0000	0.0006	−0.0043	0.0157
	(−0.0369)	(0.4703)	(−0.5415)	(0.8584)
Adj. R^2	−0.26%		−0.18%	

Note: This table considers the impact of the financial crisis. We include a dummy for the financial crisis at the second stage of the Fama–MacBeth (1973) cross-sectional regression. The regressions are modified as follows,

First stage:

$$R_{i,t+1} = \lambda_{0,t} + \lambda_{1,t} IE_{i,t} + \Lambda control_{i,t} + \varepsilon_{i,t+1},$$

Second stage:

$$\lambda_{k,t} = \gamma_{0,k} + \gamma_{1,k} dummy_t + \epsilon_{k,t}, k = 0, 1,$$

where $\lambda_{k,t}$ are the coefficients of the idiosyncratic asymmetry and control variables in the first stage, k represents the kth variable, and i represents the ith commodity. We report $\gamma_{0,k}$ and $\gamma_{1,k}$ from the second stage, where $\gamma_{1,k}$ indicates the effect of the financial crisis on the coefficients. Newey–West t-statistics are reported in parentheses. Variables are defined in Appendix A. The sample period is January 1987 to May 2018.

*$p < 0.10$.

**$p < 0.05$.

TABLE B4 Robustness check at the characteristic level: Different rolling-over method.

	R_{t+1}				
	(1)	(2)	(3)	(4)	(5)
IE_t	−0.0328***	−0.043***	−0.027*	−0.0316**	−0.0357**
	(−2.7589)	(−2.902)	(−1.7949)	(−2.2753)	(−2.1445)
Volatility$_t$		−0.0032	−0.0016	0.0048	0.0034
		(−0.1936)	(−0.0985)	(0.3105)	(0.184)
Volume$_t$		−0.0044	−0.0025	0.0029	−0.0106
		(−0.2205)	(−0.1165)	(0.1361)	(−0.4802)
Open interest$_t$		−0.0118	−0.0239	−0.0082	−0.0043
		(−0.5846)	(−1.1683)	(−0.4104)	(−0.2038)
$R_{t-12,t-2}$		0.0107			0.0223
		(0.3573)			(0.7665)
R_{t-1}			0.0205		0.0286*
			(1.2249)		(1.7721)
$R_{t-60,t-2}$				−0.0078	−0.028
				(−0.3484)	(−1.0628)
Intercept$_t$	0.0004	0.0012	−0.0007	−0.0059	−0.0024
	(0.4293)	(0.1616)	(−0.1132)	(−1.0795)	(−0.3116)
Adj. R^2	0.40%	10.76%	10.69%	9.07%	18.21%

Note: This table reports the results of the Fama–MacBeth (1973) cross-sectional regressions of the commodity futures returns on idiosyncratic asymmetry (IE) and control variables. We roll over to the next nearest contract 1 month before maturity. The control variables include a set of characteristics of commodity futures. Newey–West *t*-statistics are reported in parentheses. Variables are defined in Appendix A. The sample period is January 1987 to May 2018.

*$p < 0.10$.

**$p < 0.05$.

***$p < 0.01$.

TABLE B5 Robustness check at the factor level: Additional risk factors.

	R_{t+1}			
	(1)	(2)	(3)	(4)
β_t^{IE}	0.0151***	0.0096***	0.0132**	0.0155***
	(3.0679)	(2.8841)	(2.3436)	(3.3578)
β_t^{lr}	0.001			0.0003
	(0.1967)			(0.0599)
$\beta_t^{inflation}$		−0.0004		−0.0005
		(−1.2305)		(−1.4945)
$\beta_t^{sentiment}$			0.0173	0.0094
			(1.0908)	(0.5107)
β_t^{MARKET}	0.0023	0.0049	−0.0004	0.0035
	(0.2294)	(0.4418)	(−0.0423)	(0.2973)
β_t^{TS}	−0.0265	−0.0079	−0.0027	−0.007
	(−1.1392)	(−1.2792)	(−0.3938)	(−0.842)
β_t^{HP}	0.1135	0.0053	0.0237	0.0062
	(1.2235)	(0.2808)	(1.1866)	(0.3021)
β_t^{MOM}	−0.0998	0.0006	−0.0043	−0.0027
	(−1.0104)	(0.0661)	(−0.4609)	(−0.2853)
Intercept$_t$	0.0048***	0.0042**	0.0046***	0.0044**
	(3.0875)	(2.4009)	(3.2004)	(2.4996)
Adj. R^2	28.33%	26.68%	29.61%	34.92%

Note: This table presents the robustness results of the pricing of the idiosyncratic asymmetry (IE) factor after controlling for liquidity, inflation, and sentiment. It reports the time-series average of the slope coefficients and their *t*-values from the two-pass Fama–MacBeth (1973) cross-sectional regressions of the commodity futures returns on the factor loadings using Equation (7). Newey–West *t*-statistics are reported in parentheses. Variables are defined in Appendix A. The sample period is January 1987 to May 2018.

**$p < 0.05$.

***$p < 0.01$.