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- 김대환 드림

Low-High Basis Factor in the Commodity Futures Market

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Abstract

We consider the profit to the "buy low-basis commodities and sell high-basis commodities" strategy as a pricing factor in the commodity futures market. We call this factor the low-high basis factor, or LHB factor, in short. We first document the significant premium accruing to the LHB factor. We then report a substantial reduction in the pricing errors of factor models. In particular, the zero-intercept hypothesis of factor models is no longer rejected by the data once the LHB factor is included in the model. Finally, we show that the time-variation in the LHB factor return can be predicted, to some extent, by the implied volatility spread. We relate our findings to Keynes' normal backwardation theory and Kaldor's theory of storage and convenience yield.

Keywords

Low-high basis factor, Implied volatility, Normal backwardation, Theory of storage, Convenience yield

JEL Classification

G10, G12, G13

1. Introduction

Since Dusak (1973), a number of economists have attempted to explain the cross-section of commodity futures returns using the capital asset pricing model and its variants.[1] These attempts, however, have had only a limited success. The models have a rather low explanatory power; more importantly, the zero-intercept restriction is rejected by the data. There is certainly a room for improvement.

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[1] Dusak (1973) estimates the standard capital asset pricing model (CAPM), whereas Breeden (1980) and Jaganathan (1985) estimate consumption and intertemporal CAPM. Carter, Rausser, and Schmitz' (1983) and Bessembinder (1992) include a hedging pressure variable in the analysis.

In this paper, we propose a new pricing factor that improves the existing CAPM-type factor models. Our new pricing factor is based on a popular investment strategy among commodity futures investors. The strategy buys low-basis futures and sells high-basis futures. Basis is defined as the ratio of the futures price over the spot price (or a longer-term futures price over a shorter-term futures price). Thus, in this strategy, we may buy commodities with downward sloping futures curve, and sell commodities with upward sloping futures curve.[2] We call the profit to this strategy "the low-high basis factor," or "the LHB factor," in short.

That the basis is linked to the subsequent return has been a central idea since Kaldor's (1939) theory of storage. As Fama and French (1987) clarify, the basis can be decomposed into the expected change in the spot price and the return to the futures. Confirming this link between the basis and the return, Gorton, Hayashi, and Rouwenhorst (2012) report a large profit to the strategy of buying low-basis futures and selling high-basis futures.[3] Given this evidence, it is natural to consider the profit to this strategy as a potential pricing factor.

Another motivation for the LHB factor is provided by recent research on the currency market. It has been shown that the currency carry trades—buying high interest currencies and selling low interest currencies—earn significant excess returns. Lustig, Roussanov, and Verdelhan (2008) show that the return to carry trades can be a powerful pricing factor in the currency market, i.e. the beta with respect to this carry return explains the cross-section of excess returns. Note the similarity between the carry factor of Lustig, Roussanov, and Verdelhan (2008) and our LHB factor. A high interest currency has a low basis, and a low interest currency has a high basis.[4] Thus, buying low-basis assets and selling high-basis assets in the currency market amounts to the carry trades; in this sense, the carry factor of Lustig, Roussanov, and Verdelhan (2008) is also an LHB

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[2] This strategy is often called the backwardation-contango strategy. Different people assign somewhat different meanings to the term "backwardation." Some compares futures price to the spot price, whereas others compare it to the expected spot price. To minimize confusion, we avoid the name backwardation-contango strategy.

[3] Gorton, Hayashi, and Rouwenhorst (2012) defined the basis in the opposite way, so low basis in our sense corresponds high basis in their sense. Our definition of basis corresponds to that of Fama and French (1987).

[4] This is ensured by the covered interest parity (CIP). When CIP holds, the basis equals the interest rate of the base currency over the interest rate of the given currency. We assume that the exchange rate is quoted such that the value of the given currency is expressed in terms of the number of the base currency unit.

factor.

Our LHB factor can also be compared to the HML factor of Fama and French (1993). The basis is comparable to the book-to-market ratio (or the price-to-earnings ratio) in that it is indicative of the "fundamental" value of the commodity futures. Thus, if one were to create a value factor for commodity futures market, the LHB factor would be the natural choice.

Our empirical findings can be easily summarized. First, we report that the LHB factor has significant return over the 30-year period from 1981 to 2010, confirming the pattern reported by Gorton, Hayashi, and Rouwenhorst (2012). Our analysis is based on the balanced panel data, which include 22 commodities. Second, we find that the pricing error is substantially reduced when the LHB factor is added to the factor model. The pricing error is measured as the deviation from the zero-intercept restriction of the factor model. In a formal test based on the F statistic, the p value is between 3% and 12% when the LHB factor is not included; when the LHB factor is added, the p value is between 8% and 26%. Finally, we examine the predictability of the LHB factor return. We regress the LHB factor return on the three spread variables—the basis spread, the hedging pressure spread, and the implied volatility spread. It turns out that only the volatility spread is a significant predictor of the LHB factor return.

The oldest theory for the commodity futures returns is the normal backwardation theory of Keynes (1930). While there are more than one interpretation of the theory[5], one key component is the idea that commodity futures investors get reward for bearing risk. Our analysis suggests that an important part of this risk can be captured by the exposure to the LHB factor. The last part of our analysis also suggests that the common risk in the commodity futures market is related to the cross-sectional distribution of price volatility.

Price volatility has an important role in the theory of storage as well. Developing the idea of Kaldor (1939) further, Brennan (1958) identifies three components of the basis: the outlay for storage, the convenience yield, and the risk. The risk part is thought be a function of price volatility. The convenience yield is affected by the inventory level and the possibility of stock-out, both of which have implications on price volatility. More recently, Litzenberger and Rabinowitz (1995) emphasize the real option aspects of inventory, whose value is affected by price volatility.

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[5] Disagreement is on who are these investors (speculators? traders on the long-side?) and on what type of risk is being rewarded (price volatility? systematic risk?).

The remainder of this paper is organized as follows. In Section 2, we review the related literature. Section 3 briefly describes the data and the methodology. The next two sections present empirical findings. Section 4 discusses factor model estimates, and Section 5 discusses time-variation in the LHB factor. We conclude in Section 6. Further details on the data and the methodology are included in the appendix.

2. Related Literature

Our analysis continues the line of research that applies factors models to explain the cross-section of commodity futures returns. Dusak (1973) is the first to estimate the capital asset pricing model (CAPM) for commodity futures. As the proxy for market return, Dusak uses the S&P 500 index return. Beta for wheat, corn, and soybean, the three commodities of her choice, turned out not to be significant. Carter, Rausser, and Schmitz (1983) extend Dusak's analysis in two ways. They include a variable measuring hedging pressure, and they use the equal weighted average of the stock market index return and the commodity market index return. They find beta to be significant. However, they also found that hedging pressure is even more significant that beta. Breeden (1980) estimates consumption CAPM and finds significant beta for some commodities, but not for all. Bessembinder (1992) finds that CAPM beta to be significant in the Fama-MacBeth (1973) framework, which also included a hedging pressure and volatility variables. Bessembinder also estimates multi-factor models which includes macroeconomic variables as factors. The above studies focus on whether the betas are significant. Having failed to establish the significance of the betas, they do not proceed to test the main implication of the factor models, i.e. the zero-intercept restriction. Jagannathan (1985) takes a somewhat different route, and estimates the Euler equation implied by a representative-agent equilibrium model. That is, he estimates the intertemporal CAPM. The data, however, reject the model.[6]

While not adopting the factor model framework, other authors have also investigated the cross-section of commodity futures return, and the role of certain characteristics in it. Fama and French (1987) regress returns on basis, for each commodity futures, and find the basis to be significant. The justification for this regression is that the basis can be decomposed into the risk premium (i.e. return) and the forecast of future spot price. That is, the regression is a way to quantify this decomposition. Gorton, Hayashi, and Rouwenhorst (2012) report a strong negative correlation between basis and return, and the significant return to the long-short portfolio that is long on

[6] Miffre and Rallis (2007) also use a factor model in evaluating the momentum strategy in the commodity futures market.

low basis commodities and short on high basis commodities.[7] The theoretical justification comes from the theory of storage. These two studies, however, do not adopt the factor model framework, which make them quite different from the current study.

The idea that there is positive excess return in the commodity futures market can be traced back to the writing of Keynes (1930). Keynes has noted that futures price, F_t, can be lower than the expected spot price in the future, $E(S_T)$, and the difference between these two is the reward for the speculators who take long position in the futures. This situation is known as the 'normal backwardation.' Later authors, including Kaldor (1939) and Cootner (1960), have noted that speculators may take short position, in which case 'contango' rather than backwardation would be normal. The nature of the reward, $E(S_T) - F_t$, has been debated for a long time. Some authors have viewed it as the reward for taking a systematic risk, which led to the attempts to develop and estimate factor models. Others have viewed it as the result of hedging pressure. The current paper continues the tradition of the former.

Our proposed factor is based on the basis, which has a central role in the theory of storage. Initially, the theory has aimed to answer why people are willing to carry inventory when futures price, F_t, is lower than the spot price, S_t. When F_t is lower than S_t, i.e. when the basis is low, the spot price is likely to go down and there is little reason to carry inventory. The answer, first suggested by Kaldor (1939) and further developed by Working (1949) and Brennan (1958), is the convenience yield—the benefit to the inventory holder. Recently, Litzenberger and Rabinowitz (1995) clarified that the inventory holder has a real option, i.e. the option to sell the commodity. Facing the possibility of stock-out, this option can be valuable, and the wedge between F_t and S_t can be large. In interpreting our empirical results, we emphasize the link between the possibility of stock-out and the price volatility. Stock-out corresponds to extremely high price. Thus, the possibility of stock-out can be reflected in price volatility, to some extent.

Constructing a factor out of the basis is not a new idea. It is, in fact, a well-known concept in the literature on the foreign exchange market. Lustig, Roussanov, and Verdelhan (2008) make a currency market factor out of interest rate differentials, which equal the basis under the covered interest parity. This factor is known as the currency carry factor. Pojarliev and Levich (2008) use this factor in analyzing the performance of currency fund managers. Kim and Song (2012) also use this factor in multi-factor models of currency returns. That the basis may have similar role in the currency market and in the commodity futures market has been made clear by Fama and French (1987). Fama and French (1987) decompose the basis in the commodity futures using the

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[7] See footnote 3.

framework that has been developed for currency market basis by Fama (1984).

From the literature on the equity value premium, we borrow the idea that the premium may be predicted by the spread in individual characteristics. Asness, Friedman, Krail, and Liew (2000) and Cohen, Polk, and Vuolteenaho (2003) suggest that the spread in price-to-earnings ratio and the spread in earnings growth help to predict the value premium. In a cross-country analysis, Kim (2012) shows that the same spreads help to explain the cross-country variation of the value premium as well. In the current study, we take the spreads in the basis, the hedging pressure, and the implied volatility as predictor variables for the LHB factor return.

3. Data and Methodology

In this section, we provide a brief description of the data and the estimation technique that we use. Further details are provided in the appendix.

Our analysis is based on commodity futures market data for the 30-year period between January 1981 and December 2010. We have collected futures price data from Commodity Research Bureau database. We have selected 22 commodities for which complete price series are available for the 30-year period.[8] Implied volatilities for the same list of commodities have also been obtained from Commodity Research Bureau database. These series start from April 2000. The data on large traders' positions are from Commitment of Traders, which is published by Commodity Futures Trading Commission.

As we adopt multi-factor framework, we motivate our estimation from the arbitrage pricing theory (APT), rather than from the CAPM. A multi-factor model can be expressed by the following system of equations:

$$\mathrm{r}_t = \alpha + \beta f_t + \varepsilon_t \quad (1)$$

r_t is a list of asset returns, and f_t is a list of factor returns. When there are N assets and k factors, r_t, α, ε_t are N-by-1 vectors, β is an N-by-k vector, and $\mathrm{f_t}$ is a k-by-1 vector. $\mathrm{f_t}$ is not necessarily de-meaned. The arbitrage pricing theory (APT) implies that there exists a k-by-1 vector λ such that

$$\mathrm{E}(r_t) = \beta\lambda \quad (2)$$

[8] We carried out a preliminary analysis using the price data from Bloomberg, and obtained essentially the same results. It appears that our results are quite robust to changes in the time period and the list of commodities as well.

λ is called the factor price. When the factor returns are calculated out of zero-investment long-short portfolio of N assets, the factor price equals the mean of the factor return[9]: $\lambda = \mathrm{E}(\mathrm{f_t})$. Thus,

$$E(\mathrm{r}_t) = \beta E(f_t) \qquad (3)$$

From (1), we know $E(\mathrm{r}_t) = \alpha + \beta E(f_t)$. Thus, we obtain the main implication of the factor model, i.e. the zero-intercept restriction:

$$\alpha = 0 \qquad (4)$$

To test this restriction, we use the F test. This test has been discussed by many authors, including Gibbons, Ross, and Shanken (1989). See the appendix for the exact formula.

4. Low-High Basis Factor and the Cross-section of Expected Returns

In this section, we present the factor model estimates, with and without the low-high basis (LHB) factor. We show that the LHB factor substantially reduces the pricing error of the factor model. We first discuss the return and basis variables and the factors; then we proceed to the factor model estimates.

For the return calculation, we follow the "nearest-maturity contract formulation": for each day, we identify the nearest-maturity contract that has at least 5 calendar days remaining until the last trade date.[10] From the nearest-maturity contracts, we create a single price index for each commodity. The price index reflects any changes of contracts, though it does not account for the transaction cost. Monthly return is calculated from this price index.

We define basis as the second nearest-maturity contract price over the nearer-maturity contract price,[11] with the adjustment for the interval between two maturity dates. More specifically, the basis is defined as $100\left[(F_{2t}/F_{1t})^{(1/d)} - 1\right]$, where F_{1t} and F_{2t} are the nearer-maturity and the second nearest-maturity contract prices, respectively, and d is the number of month between two

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[9] This can be easily verified by substituting one element of $\mathrm{f_t}$ for one element of $\mathrm{r_t}$ in (2). The element of β that corresponds to the chosen factor will be one, and all else will be zero, showing the identity between the expected factor return and the factor price.

[10] That is, our "roll-over" date is 5 calendar dates prior to the expiration date. This corresponds to traders' rollover strategy. Rollover at the last possible moment faces greater uncertainty.

[11] Alternatively, we could use the spot price in the denominator. The CRB database includes spot prices, but the quality of these data seems questionable. Also, the coverage is limited. So we do not follow this alternative. Gorton, Hayashi, Rouwenhorst (2012) also calculate the basis as we do in this paper, except for the fact that their basis is the inverse of our basis. See footnote 3.

maturity dates.

Table 1 shows the univariate statistics on monthly returns and end-of-the-month basis for each of 22 commodities included in the analysis. One can see that average monthly returns are mostly positive, between 0% and 1% except for a few instances. Average basis is mostly positive as well, suggesting that commodity markets are more likely to exhibit upward-sloping forward curve.

In the factor models, we include various combinations of the following 4 factors: the stock market factor, the commodity market factor, the combined stock-and-commodity-market factor ("S&C factor"), and the LHB factor. The first three of these factors have been used in the prior literature. Dusak (1973) and Bessembinder (1992) have used the stock market factor; Miffre and Rallis (2007) have used the commodity market factor as well as the stock market factor; Carter, Rausser, and Schmitz (1983) have used the combined stock-and-commodity-market factor. The LHB factor is our contribution.

The stock market factor represents the overall movement in the global stock market, and is calculated as the MSCI World Index return over the 3-month US government yield. The commodity market factor represents the overall movement in the commodity futures market. We use the S&P Goldman Sachs Commodity Index return for this factor. Note that we do not subtract the riskfree rate from the commodity factor. The commodity index is from futures contracts, and buying futures contracts does not require investment.[12] Therefore, the return to this index is already "excess return," and there is no need to subtract the riskfree rate. The S&C factor is an equal weighted average of the stock market factor and the commodity market factor.

The LHB factor is the profit to the strategy that buys low-basis commodities and sells high-basis commodities. Note that the low (high) basis commodities are the ones whose futures curves have low (high) slope. At the beginning of each month, we rank all 22 commodities by basis, from the lowest to the highest. Then we buy those at the lowest quartile and sell those at the highest quartile. In each of the long side and the short side, commodities are equally weighted.[13]

In Table 2, we show summary statistics for factor returns. For the 30-year period we are examining, the stock market has the average monthly excess return of 0.42%, whereas the commodity market has the average monthly return of 0.39%. The standard deviation is higher for the commodity

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[12] Margin may be required. We ignore the margin requirement, as it varies across investors.

[13] The actual contracts that we buy are the nearest-maturity contracts. These are the ones that have been selected for the return statistics in Table 1.

market; thus, the Sharpe ratio is higher for the stock market. By construction, the S&C factor return is just the average of the stock market and the commodity market.

The LHB factor has a large average return of 0.80%. This confirms the pattern reported by Gorton, Hayashi, and Rouwenhorst (2012). It also confirms the idea that is popular among futures market participants: the strategy of buying low-basis commodity and selling high-basis commodity is profitable. The standard deviation of the return is relatively large at 5.39%, but it is somewhat smaller than the standard deviation of the commodity market. That is, buying low-basis commodity and selling high-basis commodity appears more attractive than buying the entire commodity market.

Table 2 also reports the correlations among the four factors. The LHB factor has insignificant correlation with the stock market factor and also with the commodity market factor. The latter two factors have somewhat positive correlation. The S&C factor, by construction, has large correlation with the stock market factor and the commodity market factor.

We estimate nine variants of the factor models. We first estimate four specifications without the LHB factor: (i) a single factor model with the stock market factor, as in Dusak (1973) and Bessembinder (1992), (ii) a single factor model with the commodity market factor, (iii) a two-factor model with the stock and the commodity market factors, as in Miffre and Rallis (2007), and finally (iv) a single factor model with the S&C factor, as in Carter, Rausser, and Schmitz (1983). We also estimate (v) a single factor model with the LHB factor. And we estimate the first four models including the LHB factor: (vi) a two-factor model with the stock market factor and the LHB factor, (vii) a two-factor model with the commodity market factor and the LHB factor, (viii) a three-factor model with the stock and commodity market factors and the LHB factor, and finally (ix) a two-factor model with the S&C factor and the LHB factor.

Table 3 shows the estimates for models (iii), (iv), (viii), and (ix).[14] We are primarily interested in the significance of the intercept estimates. In Panel A, which does not include the LHB factor, the intercept estimate is significant for 5 commodities. In Panel B, which includes the LHB factor, the intercept is significant for 4 commodities. One only of them is significant at the 5%, indicating some improvement over the model in Panel A. As we discuss later, the difference between these models is in fact quite substantial, when we examine the F test. The model in Panel C is similar to the model in Panel A; the stock and the commodity factors in Panel A are combined into the S&C

[14] Estimates for all other models are available upon requests. We do not include them here to save the space.

factor in Panel C. The latter appears to explain more of the commodity returns than the former. This has been noted by Carter, Rausser, and Schmitz (1983). Comparing Panel C and Panel D, we observe minor improvement when the LHB factor is added. The intercept estimate is significant for 4 commodities in Panel C, whereas the intercept estimate is significant for 3 commodities in Panel D. We do not see much difference in terms of R squared.

The improvement is more noticeable when we examine the test of zero-intercept restriction. In Table 4, we report the F test statistics and the associated p values, for all nine models that we consider. The null hypothesis is that all intercept terms are simultaneously zero, and a high p value supports this hypothesis. Among the four models without the LHB factor, only the last model with the S&C factor has the p value above 10%. In the other models, the zero-intercept restriction is rejected at the 10% significance level. In case of the model with the commodity market factor and the model with the stock and the commodity factor, the zero-intercept restriction is rejected at the 5% significance level. When the LHB factor is added, however, the test statistics increase substantially. None of the models with the LHB factor is rejected at 10% significance level. The worst case—the three factor model with the stock and the commodity market factors and the LHB factor—has the p value of 10%. In all cases, adding the LHB factor increases the p value two times or more. The highest p value is achieved by the two-factor model with the S&C factor and the LHB factor.

5. Time-Variation in Low-High Basis Factor

In the previous section, we have showed that the LHB factor has explanatory power for the cross-section of commodity futures returns. In this section, we explore the time-variation in the LHB factor. We examine whether the spread in the basis, the hedging pressure, and the implied volatility can predict the LHB factor return. We find that the implied volatility spread has predictive power, whereas the other two variables do not.

The idea that the spread can predict the factor return comes from the literature on the stock market. From the decomposition of the price-to-earnings ratio, Asness, Friedman, Krail, and Liew (2000) have suggested that the spread in price-to-earnings ratio and the spread in earnings growth help to predict the value premium. Cohen, Polk, and Vuolteenaho (2003) confirmed the pattern in the context of the book-to-market ratio. Applying the idea to our case, it is natural to consider the spread in the basis as a predictor of the LHB factor return. The basis was the variable by which the assets were ranked. Moreover, the basis is similar to the price-to-earnings ratio and the book-to-market ratio in that it is indicative of the intrinsic value of the asset.

We consider two more spread variables: the spread in the hedging pressure and in the implied volatility. The importance of the hedging pressure in explaining commodity futures return is well known. Cootner (1960) has interpreted normal backwardation idea as being driven by the hedging pressure. Carter, Rausser, and Schmitz (1983) and Bessembinder (1992) have shown empirically the relevance of the hedging pressure. These authors have measured the hedging pressure out of the Commitment of Traders data; we follow this approach. Bessembinder (1992) has also shown the relevance of volatility. He has included the volatility in his analysis in the belief that the "residual risk," not captured by CAPM-beta, may affect the futures return. The importance of volatility is also apparent in the theory of storage. One component of the storage cost is the convenience yield, which is a function of the possibility of stock-out and price hike. Litzenberger and Rabinowitz (1995) clarify the real option aspects of the convenience yield, and consequently, the relevance of the volatility.

Each spread variable is calculated as the difference between the 12.5th and 87.5th percentiles. These percentiles are the median values of the top and the bottom quartile portfolios—the underlying portfolios of the LHB factor. The hedging pressure is calculated as hedgers' net long position relative to all open interest. All the information is from the Commitment of Traders reports.[15] The Commitment of Traders reports are released weekly, with more than one week's delay. The end-of-month hedging pressure is based on the last weekly report of the month, without considering the release gap. Volatility is implied volatility from the futures options. The volatility spread is available from April 1990, so the subsequent analysis is based on the period between April 1990 and December 2010. Table 5 reports univariate statistics of the three spread variables and the correlation among them. Interestingly, the hedging spread is negatively correlated with the basis spread, and to a less extent, with the volatility spread.

The regression results are reported in Table 6. The first three columns of the table show the estimates when each spread variable is included one at a time. The last column shows the regression where all three spread variables are included at the same time. The pattern is the same in both cases. The volatility spread is a significant predictor, whereas the other two predictors are not. R squared is not very high, so the predictability may not be economically significant.

[15] Following the convention, we identify 'commercial traders' as hedgers. By ignoring the positions of 'non-reportable' we are implicitly assuming that small traders as speculators.

6. Conclusion

We find that the LHB factor substantially reduces the pricing error of factor models for commodity futures returns. The pricing error is minimal when the factor model includes the S&C factor (the combined stock-and-commodity-market factor) and the LHB factor. Regarding the time-variation in the LHB factor, we find that the volatility spread can predict the LHB factor return, to some extent. The basis spread and the hedging spread turn out not to be significant. Our analysis suggests the relevance of volatility to the common factor in the commodity futures market.

The LHB factor was motivated by the currency carry factor of Lustig, Roussanov, and Verdelhan (2008). Both factors are based on the basis, the ratio of two prices with different maturities. Another interpretation is that the LHB factor is comparable to the equity value factor, e.g. that of Fama and French (1993). Both factors are constructed based on indicators of the intrinsic value. Exploring the relationship among these factors in the equity market, the currency market, and the commodity market is a topic that we plan to pursue further.

Appendix A. F Test Formula

Consider the following system of equations:

$$\mathrm{r}_t = B'x_t + \varepsilon_t, \qquad \varepsilon_t \sim N(0, \Sigma)$$

where r_t, x_t, ε_t are N-by-1 vectors, B is a (1+k)-by-N vector, Σ is an N-by-N matrix, and t runs from 1 to T. By horizontally stacking the transpose of column vectors, r_t, x_t, ε_t, we define $\mathrm{R}, \mathrm{X}, \text{and } \mathrm{E}$ so that

$$\mathrm{R} = XB + E$$

Then the OLS estimate can be written as:

$$\begin{aligned}\hat{\mathrm{B}} &= (X'X)^{-1}X'R \\ &= \mathrm{B} + (X'X)^{-1}X'E\end{aligned}$$

By vectorizing $\hat{\mathrm{B}}$ (taking the first column, and then the second column, and so on), we may express the distribution of $\hat{\mathrm{B}}$ as following:

$$\mathrm{vec}(\hat{\mathrm{B}}) \sim \mathrm{N}[vec(B), \Sigma \otimes (\mathrm{X'X})^{-1}]$$

The first column of X includes only 1. So we may partition X and B as follows:

$$\mathrm{X} = [1 \; F]$$
$$\mathrm{B} = [\alpha \; \beta]$$

Then the distribution of $\hat{\alpha}$ is:

$$\hat{\alpha} \sim \mathrm{N}\{\alpha, \Sigma[(\mathrm{X'X})^{-1}]_{11}\}$$

The estimator of Σ, $\hat{\Sigma} = E'E/T$, has the following Wishart distribution:

$$T\hat{\Sigma} \sim W(\Sigma, T - k - 1)$$

Note that k does not include the constant term. From the distribution of $\widehat{\alpha}$, $\widehat{\alpha}\Sigma^{-1}\widehat{\alpha}/[(X'X)^{-1}]_{11}$ has $\chi^2(N)$ when $\alpha = 0$. Also, $\widehat{\alpha}\Sigma^{-1}\widehat{\alpha}/(\widehat{\alpha}\widehat{\Sigma}^{-1}\widehat{\alpha})$ has $\chi^2(T-k-1-N+1)$.[16] From these two distributions, we get

$$\mathrm{F} \equiv \frac{\widehat{\alpha}\left(T\widehat{\Sigma}\right)^{-1}\widehat{\alpha}}{[(X'X)^{-1}]_{11}} \frac{T-k-1-N+1}{N} \sim F(N, T-k-1-N+1)$$

Appendix B. Data Details

Our commodity futures price data are from the Commodity Research Bureau (CRB) database. These data have been used by many, including Gorton and Rouwenhorst (2006), Gorton, Hayashi, Rouwenhorst (2012), and Shen, Szakmary, and Sharma (2007). These authors have based their analysis on unbalanced panels; thus, they have included a larger number of commodities. Our analysis is based on a balanced panel; so the number of commodities included in the analysis is smaller. We have excluded all the commodities whose price series start after January 1981. We have also excluded the metal commodities that are traded on the London Metal Exchange. The CRB data on these commodities are limited.[17] Moreover, the Commitment of Traders data are not available for these commodities, making these commodities less attractive for our purpose. After the selection, we have 22 commodities, as listed in Table 1.

For the return calculation, we select the nearest-maturity contract for each day. However, we exclude those contracts with very short history. The following contracts have been excluded even if there are price data in the CRB database: G, M, and X for coffee, G, J, M, Q, V, and X for copper and silver, F and X for corn, Q and U for cotton, F, H, K, N, U, and X for gold, lean hogs, and live cattle, Z for lumber, F, G, J, K, N, Q, V, and X for palladium, G, H, K, M, Q, U, X, and Z for platinum, F, J, and M for pork bellies, X for soybean meal and soybean oil, and F and U for sugar. (F, G, H, J, K, M, N, Q, U, V, X, and Z indicate the expiration month of each contract, from January to December.) For the implied volatility, we select only those options contracts for which the corresponding futures contracts are used in the return calculation. There are three exceptions to this rule: Q and V of soybean oil are excluded, and F of copper and silver are also excluded, all of them due to short history. Implied volatility for palladium is excluded again due to short history.

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[16] Note that N and 1 come from $\widehat{\alpha}$. See Proposition 8.9 of Eaton (2007).

[17] There are no contract-by-contract data for these commodities.

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Tables

Table 1. Return and Basis by Commodity

Below statistics for monthly return and end-of-month basis are reported for each commodity, for the period from January 1981 to December 2010. The monthly return is calculated as the percentage change in the price of the nearest contract, with the adjustment for the possible change of the nearest contracts during the month. The basis is calculated as the percentage difference between the prices of the second-nearest and the nearest contracts (i.e. the second-nearest-contract price over the nearest-contract price, expressed in percent). The basis is adjusted for the difference in the expiration dates of the two contracts, i.e. the resulting figure is the rate of change over one month. T is the number of observations; SD is the standard deviation.

		Return				Basis			
	T	Mean	SD	Min	Max	Mean	SD	Min	Max
Cocoa	360	0.07	8.77	-25.39	36.54	0.61	0.98	-5.77	2.91
Coffee	360	0.61	11.03	-31.27	50.60	0.38	1.49	-7.15	4.98
Copper	360	1.09	8.23	-36.47	39.74	-0.14	1.16	-6.79	1.66
Corn	360	-0.16	7.22	-20.31	45.82	0.86	1.53	-12.22	2.55
Cotton	360	0.20	7.57	-22.70	30.53	0.39	2.21	-22.34	9.08
Feeder Cattle	360	0.48	4.08	-20.58	14.83	-0.20	1.24	-4.94	5.40
Gold	360	0.09	4.73	-17.98	19.02	0.43	0.27	0.03	1.43
Heating Oil	360	1.16	9.86	-28.86	44.45	-0.13	2.43	-15.27	4.36
Lean Hogs	360	0.45	7.79	-26.12	30.20	0.42	4.29	-10.26	13.19
Live Cattle	360	0.74	4.47	-24.48	14.50	-0.10	1.77	-4.74	3.94
Lumber	360	-0.48	9.39	-23.87	45.24	1.19	2.49	-7.54	7.05
Oats	360	0.61	10.29	-26.74	93.42	0.66	2.19	-10.03	3.82
Orange Juice	360	0.61	9.02	-22.13	61.01	0.44	1.45	-4.86	3.51
Palladium	360	0.96	9.97	-33.88	46.89	0.15	0.60	-4.51	4.91
Platinum	360	0.51	6.93	-31.86	34.03	0.15	0.47	-1.81	1.59
Pork Bellies	360	0.67	11.35	-33.87	44.11	-0.27	1.85	-7.83	9.29
Silver	360	0.21	8.07	-27.52	28.84	0.50	0.47	-0.06	7.35
Soybean Meal	360	0.87	7.50	-24.00	27.09	-0.31	2.28	-19.27	8.66
Soybean Oil	360	0.34	7.86	-28.13	43.99	0.47	1.09	-6.15	2.26
Soybeans	360	0.48	6.97	-25.12	27.99	0.19	1.60	-12.37	1.87
Sugar	360	0.21	11.25	-29.70	67.42	0.22	1.74	-5.91	4.68
Wheat	360	-0.12	7.39	-21.14	38.50	0.60	1.73	-8.72	3.24

Table 2. Factor Return

Below statistics for monthly returns are reported for each factor, for the period from January 1981 to December 2010. “Stock” refers to the stock market factor, which we calculate out of the MSCI World index. Three-month Treasury Bill rate is subtracted from the stock market factor. “Cmdty” refers to the commodity futures market factor, which we calculate out of S&P Goldman Sachs Commodity Index. “S&C” refers to the combined stock-and-commodity-futures-market factor, which is the simple average of the stock market factor and the commodity futures market factor. “LHB” refers to the low-high basis factor, i.e. the return to the strategy of buying low basis commodities and selling high basis commodities. T is the number of observations; SD is the standard deviation.

	T	Mean	SD	Min	Max	Correlation			
						(1)	(2)	(3)	(4)
(1) Stock	360	0.42	4.44	-19.00	11.25	1.00			
(2) Cmdty	360	0.39	5.55	-27.77	21.10	0.19	1.00		
(3) S & C	360	0.41	3.87	-23.38	15.08	0.71	0.83	1.00	
(4) LHB	360	0.80	5.39	-30.59	18.06	-0.07	0.01	-0.03	1.00

Table 3. Factor Model Estimates

Factor models are estimated for each commodity. The dependent variable is the return of each commodity. The explanatory variables are indicated in the model name. “Stock” refers to the stock market factor, “Cmdty” refers to the commodity futures market factors, “LHB” refers to the low-high basis factor, and “S&C” refers to the combined stock-and-commodity-futures-market factor. See Table 2 for further description of these factors. Monthly data from January 1981 to December 2010 are used for the regressions. Coefficient estimates are reported first, followed by t statistics inside square brackets. * and ** indicate significance at 10% and 5%, respectively.

A. “Stock + Cmdty” Model

	Constant			Stock			Cmdty			R sq.
Cocoa	-0.04	[-0.09]		0.05	[0.52]		0.23	[2.74]	**	0.02
Coffee	0.46	[0.79]		0.24	[1.82]	*	0.11	[1.08]		0.01
Copper	0.76	[1.88]	*	0.40	[4.31]	**	0.41	[5.62]	**	0.15
Corn	-0.34	[-0.92]		0.20	[2.41]	**	0.25	[3.74]	**	0.06
Cotton	-0.01	[-0.02]		0.29	[3.29]	**	0.21	[2.89]	**	0.06
Feeder Cattle	0.43	[1.99]	**	0.05	[1.08]		0.07	[1.81]	*	0.01
Gold	-0.02	[-0.09]		0.06	[1.02]		0.22	[4.89]	**	0.07
Heating Oil	0.65	[2.11]	**	-0.16	[-2.24]	**	1.45	[25.87]	**	0.65
Lean Hogs	0.38	[0.93]		-0.01	[-0.08]		0.19	[2.60]	**	0.02
Live Cattle	0.65	[2.80]	**	0.11	[1.99]	**	0.10	[2.45]	**	0.03
Lumber	-0.71	[-1.46]		0.42	[3.82]	**	0.13	[1.42]		0.05
Oats	0.42	[0.79]		0.08	[0.69]		0.40	[4.09]	**	0.05
Orange Juice	0.49	[1.02]		0.15	[1.38]		0.15	[1.67]	*	0.02
Palladium	0.61	[1.22]		0.49	[4.28]	**	0.36	[3.90]	**	0.10
Platinum	0.23	[0.68]		0.40	[5.10]	**	0.30	[4.77]	**	0.14
Pork Bellies	0.64	[1.06]		-0.10	[-0.72]		0.18	[1.61]		0.01
Silver	-0.02	[-0.06]		0.29	[3.11]	**	0.29	[3.81]	**	0.08
Soybean Meal	0.68	[1.77]	*	0.16	[1.78]	*	0.31	[4.47]	**	0.07
Soybean Oil	0.14	[0.35]		0.19	[2.03]	**	0.30	[4.04]	**	0.06
Soybeans	0.27	[0.78]		0.18	[2.21]	**	0.32	[4.97]	**	0.09
Sugar	0.08	[0.14]		0.12	[0.86]		0.20	[1.84]	*	0.01
Wheat	-0.35	[-0.94]		0.24	[2.83]	**	0.33	[4.89]	**	0.10

Table 3. Factor Model Estimates [Continued]

B. "Stock + Cmdty + LHB" Model

	Constant			Stock			Cmdty			LHB			R sq
Cocoa	0.02	[0.05]		0.05	[0.45]		0.23	[2.76]	**	-0.07	[-0.87]		0.03
Coffee	0.49	[0.83]		0.24	[1.79]	*	0.12	[1.09]		-0.03	[-0.32]		0.02
Copper	0.76	[1.86]	*	0.40	[4.29]	**	0.41	[5.61]	**	0.00	[-0.03]		0.15
Corn	-0.14	[-0.39]		0.18	[2.18]	**	0.26	[3.89]	**	-0.24	[-3.53]	**	0.09
Cotton	-0.01	[-0.03]		0.29	[3.29]	**	0.21	[2.88]	**	0.01	[0.09]		0.06
Feeder Cattle	0.35	[1.62]		0.06	[1.26]		0.07	[1.76]	*	0.09	[2.34]	**	0.03
Gold	-0.09	[-0.39]		0.06	[1.17]		0.21	[4.86]	**	0.09	[1.98]	**	0.08
Heating Oil	0.57	[1.84]	*	-0.15	[-2.12]	**	1.45	[25.89]	**	0.10	[1.71]	*	0.66
Lean Hogs	0.34	[0.81]		0.00	[-0.04]		0.19	[2.58]	**	0.05	[0.66]		0.02
Live Cattle	0.58	[2.45]	**	0.11	[2.16]	**	0.10	[2.40]	**	0.09	[2.19]	**	0.05
Lumber	-0.63	[-1.28]		0.42	[3.74]	**	0.13	[1.45]		-0.10	[-1.08]		0.05
Oats	0.71	[1.33]		0.05	[0.44]		0.41	[4.25]	**	-0.34	[-3.55]	**	0.08
Orange Juice	0.68	[1.43]		0.13	[1.19]		0.15	[1.76]	*	-0.23	[-2.69]	**	0.04
Palladium	0.32	[0.64]		0.52	[4.64]	**	0.35	[3.88]	**	0.36	[3.90]	**	0.14
Platinum	0.07	[0.20]		0.41	[5.38]	**	0.29	[4.74]	**	0.19	[3.12]	**	0.17
Pork Bellies	0.34	[0.57]		-0.07	[-0.49]		0.17	[1.54]		0.36	[3.27]	**	0.04
Silver	-0.04	[-0.10]		0.29	[3.12]	**	0.29	[3.80]	**	0.02	[0.26]		0.08
Soybean Meal	0.73	[1.87]	*	0.15	[1.72]	*	0.32	[4.49]	**	-0.05	[-0.75]		0.07
Soybean Oil	0.21	[0.52]		0.18	[1.94]	*	0.30	[4.07]	**	-0.08	[-1.10]		0.07
Soybeans	0.31	[0.87]		0.17	[2.15]	**	0.32	[4.98]	**	-0.04	[-0.68]		0.09
Sugar	0.36	[0.61]		0.09	[0.64]		0.21	[1.94]	*	-0.33	[-3.08]	**	0.04
Wheat	-0.19	[-0.50]		0.22	[2.64]	**	0.34	[5.01]	**	-0.19	[-2.85]	**	0.12

Table 3. Factor Model Estimates [Continued]

C. "S&C" Model

	Constant			S&C			R sq
Cocoa	-0.06	[-0.12]		0.32	[2.67]	**	0.02
Coffee	0.47	[0.81]		0.33	[2.23]	**	0.01
Copper	0.76	[1.88]	*	0.81	[7.84]	**	0.15
Corn	-0.35	[-0.94]		0.47	[4.89]	**	0.06
Cotton	0.00	[-0.00]		0.48	[4.81]	**	0.06
Feeder Cattle	0.43	[1.99]	**	0.13	[2.31]	**	0.01
Gold	-0.03	[-0.14]		0.30	[4.83]	**	0.06
Heating Oil	0.51	[1.24]		1.60	[15.21]	**	0.39
Lean Hogs	0.36	[0.88]		0.22	[2.12]	**	0.01
Live Cattle	0.65	[2.80]	**	0.21	[3.50]	**	0.03
Lumber	-0.68	[-1.40]		0.49	[3.94]	**	0.04
Oats	0.39	[0.73]		0.54	[3.93]	**	0.04
Orange Juice	0.49	[1.03]		0.29	[2.40]	**	0.02
Palladium	0.63	[1.25]		0.82	[6.37]	**	0.10
Platinum	0.24	[0.71]		0.68	[7.70]	**	0.14
Pork Bellies	0.61	[1.02]		0.13	[0.83]		0.00
Silver	-0.02	[-0.06]		0.58	[5.46]	**	0.08
Soybean Meal	0.67	[1.74]	*	0.50	[5.04]	**	0.07
Soybean Oil	0.13	[0.33]		0.51	[4.86]	**	0.06
Soybeans	0.26	[0.74]		0.53	[5.77]	**	0.09
Sugar	0.07	[0.13]		0.33	[2.17]	**	0.01
Wheat	-0.36	[-0.96]		0.59	[6.16]	**	0.10

Table 3. Factor Model Estimates [Continued]

D. "S&C + LHB" Model

	Constant			S&C			LHB			R sq
Cocoa	0.00	[-0.00]		0.31	[2.65]	**	-0.07	[-0.78]		0.02
Coffee	0.50	[0.85]		0.33	[2.21]	**	-0.04	[-0.36]		0.01
Copper	0.76	[1.85]	*	0.81	[7.83]	**	0.00	[-0.02]		0.15
Corn	-0.15	[-0.42]		0.46	[4.85]	**	-0.24	[-3.49]	**	0.09
Cotton	0.00	[-0.01]		0.48	[4.80]	**	0.00	[0.04]		0.06
Feeder Cattle	0.35	[1.62]		0.13	[2.40]	**	0.09	[2.35]	**	0.03
Gold	-0.11	[-0.46]		0.31	[4.92]	**	0.09	[2.11]	**	0.07
Heating Oil	0.38	[0.92]		1.60	[15.34]	**	0.16	[2.13]	**	0.40
Lean Hogs	0.31	[0.76]		0.23	[2.15]	**	0.06	[0.76]		0.01
Live Cattle	0.58	[2.46]	**	0.21	[3.59]	**	0.09	[2.18]	**	0.05
Lumber	-0.59	[-1.20]		0.49	[3.90]	**	-0.11	[-1.20]		0.05
Oats	0.66	[1.24]		0.53	[3.87]	**	-0.33	[-3.39]	**	0.07
Orange Juice	0.68	[1.43]		0.28	[2.34]	**	-0.23	[-2.69]	**	0.04
Palladium	0.34	[0.68]		0.84	[6.61]	**	0.35	[3.83]	**	0.14
Platinum	0.08	[0.25]		0.68	[7.87]	**	0.19	[3.04]	**	0.16
Pork Bellies	0.31	[0.52]		0.14	[0.95]		0.37	[3.36]	**	0.03
Silver	-0.04	[-0.10]		0.58	[5.46]	**	0.02	[0.26]		0.08
Soybean Meal	0.71	[1.82]	*	0.50	[5.01]	**	-0.05	[-0.66]		0.07
Soybean Oil	0.20	[0.48]		0.50	[4.83]	**	-0.08	[-1.04]		0.06
Soybeans	0.29	[0.82]		0.52	[5.74]	**	-0.04	[-0.59]		0.09
Sugar	0.35	[0.58]		0.32	[2.10]	**	-0.33	[-3.04]	**	0.04
Wheat	-0.20	[-0.54]		0.58	[6.12]	**	-0.19	[-2.79]	**	0.12

Table 4. Test of Factor Models

The zero-intercept property of factor models is tested. Models are estimated using monthly data from January 1981 to December 2010, and then the F test is carried out. A low p-value indicates that the null of zero-intercept is rejected. A high p-value supports the zero-intercept hypothesis. The model name indicates which factors are included in the model. "Stock" refers to the stock market factor; "Cmdty" refers to the commodity futures market factor; "S&C" refers to the combined stock-and-commodity-futures-market factor; and "LHB" refers to the low-high basis factor. See Table 2 for further description of these factors. DF1 and DF2 are two degrees of freedom of the F test.

Model	DF1	DF2	F Stat	P Value
Stock	22	337	1.47	0.08
Cmdty	22	337	1.69	0.03
Stock + Cmdty	22	336	1.63	0.04
S&C	22	337	1.39	0.12
LHB	22	337	1.39	0.12
Stock + LHB	22	336	1.27	0.19
Cmdty + LHB	22	336	1.49	0.08
Stock + Cmdty + LHB	22	335	1.41	0.10
S&C + LHB	22	336	1.19	0.26

Table 5. Spreads

Below statistics for monthly spreads are reported for the period from April 1990 (the first month when the volatility spread is available) to December 2010. At the end of each month, for each commodity, the basis is calculated as the percentage difference between the prices of the second-nearest and the nearest contracts, and adjusted for the difference in the expiration dates of the two contracts. (See Table 1 for further description of basis.) Then the basis spread is calculated as the difference between the 12.5th and 87.5th percentiles. Hedging pressure is calculated as hedgers' net long position relative to all open interest. Hedging spread is also calculated as the difference between the 12.5th and 87.5th percentiles. Volatility is the implied volatility from the futures options. Volatility spread is also calculated as the difference between the 12.5th and 87.5th percentiles.

	T	Mean	SD	Min	Max	Correlation		
						(1)	(2)	(3)
(1) Basis spread	249	3.23	1.14	1.13	8.66	1.00		
(2) Hedging spread	249	0.55	0.11	0.25	0.91	-0.12	1.00	
(3) Volatility spread	249	25.00	9.78	12.98	131.62	0.03	-0.06	1.00

Table 6. LHB Factor vs. Spreads

The return to the low-high basis (LHB) factor is regressed to spread variables. See Table 5 for the description of spread variables. Each column represents a separate regression. Coefficient estimates are reported first, followed by t statistics inside square brackets. * and ** indicate significance at 10% and 5%, respectively.

	(1)	(2)	(3)	(4)
Constant	0.96	0.98	-0.66	-0.79
	[1.01]	[0.60]	[-0.77]	[-0.37]
Basis spread	0.00			-0.01
	[-0.01]			[-0.04]
Hedging spread		-0.04		0.30
		[-0.01]		[0.10]
Volatility spread			0.06	0.06
			[2.02]	[2.01]
			**	**
R sq.	0	0	0.0162	0.0162