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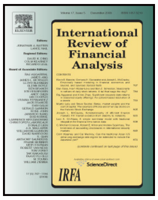

Futures markets and fundamentals of base metals

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ABSTRACT

According to the theory of storage, the interest-adjusted basis equals the warehousing cost minus the convenience yield (i.e., benefit of holding a physical commodity) per time unit. By assuming that warehousing costs relatively constant at alternative stock levels, the interest-adjusted basis will be inversely associated with the convenience yield.

In this article, we explore whether the sign of the interest-adjusted basis determines the degree of association between spot and futures returns on the six London Metal Exchange base metals—aluminum, copper, lead, nickel, tin, and zinc. In addition, we study to what extent the sign of the interest-adjusted basis correlates with the business cycle of industrial production of various countries (e.g., US, G7, OECD, Russia, and China), and with the business cycle of consumption/production of the aforementioned six base metals.

We conclude that a negative interest-adjusted basis is generally associated with booming industrial production, a negative or small metal surplus (i. e., production minus consumption), and low metal stocks. To our knowledge, this is the first study to link metal market fundamentals to futures markets dynamics.

1. Introduction

The theory of storage, developed by Brennan (1958), Telser (1958) and Working (1949), states that the convenience yield (i.e., benefit of holding a physical commodity) falls at a decreasing rate as a commodity stock level increases. In a recent article, Geman and Smith (2013) explored two implications of the theory of storage on spot and futures price behavior. Specifically, as discussed by the authors, when stock level is low, the spot price will exceed the futures price (i. e., backwardation), and the spot price return volatility will exceed the futures price return volatility. Conversely, when the stock level is high, the spot price will be lower than the futures prices (i. e., contango),[2] and the volatilities of the spot and the futures price returns will be similar. On the basis of information of spot and 3-month futures prices for the period of January 1983–June 2011, Geman and Smith found strong validation of the theory of storage for the six base metals traded on the London Metal Exchange (LME), namely, aluminum, copper, lead, nickel, tin, and zinc.

In a related strand of the literature, Tilton, Humphreys, and Radetzki (2011) focused on the association between futures and spot prices during periods of contango and backwardation. Based on a theoretical framework, Tilton et al. (2011) asserted that higher futures prices, brought about by a surge in investor demand, would have a comparable effect on the spot price during (strong) contango, but a much lesser effect on the latter during backwardation.[3] Consequently, spot and futures prices should be highly correlated during periods of strong contango and much less correlated during periods of weak contango and backwardation.

Gulley and Tilton (2014) conducted an empirical test of the above hypothesis for copper on the basis of the cost-of-carry model. Based on a sample of daily observations for the period of 1994–2011, the authors concluded that the correlation between the copper spot and futures returns was higher during strong contango. Their finding was robust to the convenience yield rate, the futures contract maturity, and to the subsample period.

In this article we show that Gulley and Tilton's findings can be rationalized within the theory of storage, as periods of contango and backwardation can be singled out by the sign of the interest-adjusted basis (i. e., warehousing cost minus convenience yield). In addition, we explore how the sign of the interest-adjusted basis relates to the

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[2] When the spot price exceeds the futures price, the futures markets is said to exhibit strong backwardation Furthermore, when the spot price is less than the futures prices but greater than its present value, the futures market is said to be in weak backwardation. On the other hand, if the futures price exceeds the spot price, the futures markets is said to be in contango. In other words, contango includes weak and zero backwardation (see, for instance, Pindyck, 2001, page 17, or Litzenberger & Rabinowitz, 1995, page 1535.).

[3] Tilton et al. argue that if investor demand drives up the futures price, this will encourage investors to buy on the spot market and sell forward on the futures market. This inter-temporal arbitrage will continue until the price difference between the spot and the futures markets returns to an amount that just covers the cost of holding stock. On the other hand, when the spot and futures markets are in backwardation or weak contango, the association between spot and futures prices is much weaker because an inter-temporal arbitrage from futures to spot markets is unfeasible. (Tilton et al. refer to strong contango as the case in which the futures price is well-above the spot price so that to cover the cost of holding stocks.)

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business cycle of industrial production of various countries and to the business cycle of consumption/production of the six LME base metals markets. We conclude that a negative interest-adjusted basis is generally associated with booming industrial production, a negative or small metal surplus (i.e., production minus consumption), and low metal stocks. To our knowledge, this is the first study to link explicitly metal demand and supply to futures markets dynamics. A previous study in this line of research is Stepanek, Walter, and Rathgeber (2013), who focused on supply risk and concluded that the convenience yield had predictive power with respect to inventory/turnover and future spot prices.[4]

This article is organized as follows. Section 2 briefly presents the cost-of-carry model, which gives a theoretical framework to our estimation process. Section 3 focuses on two statistical methods to measure association between spot and futures prices. Section 4 in turn describes the price, consumption and production data of the six base metals under analysis. Section 5 concentrates on three empirical themes: contemporaneous correlation and lagged linkages between spot and futures returns when the interest-adjusted basis varies in sign (Section 5.1); predictive performance of the business cycle of industrial production with respect to the sign of the interest-adjusted basis (Section 5.2); and, synchronicity of consumption and production cycles of a set of countries (Section 5.3). Section 6 concludes by summarizing the main empirical findings.

2. The cost-of-carry model

The cost-of-carry model establishes an arbitrage relation between futures and spot prices (see, for instance, Hull, 2014, Section 5.12). Specifically, the cost of carry measures the storage cost plus the interest that is paid to finance the asset less the income earned on the asset. The latter can take the form of a convenience yield, that is, the benefit associated with holding the physical commodity. In the absence of arbitrage, the relation between the futures price at t for delivery at T, $F_{t,T}$, and the spot price at t, S_t, is given by

$$F_{t,T} = S_t \exp[(r_t + u_t - y_t)\tau] \tag{1}$$

where $(r_t + u_t - y_t)$ represents the cost of carry, in that r_t, u_t, and y_t are, respectively, the risk-free rate, the storage cost rate, and the convenience yield at time t, and $\tau \equiv (T - t)$ is the time remaining until contract maturity.

From Eq. (1) it follows that

$$\ln(F_{t,T}/S_t) - r_t\tau = (u_t - y_t)\tau \equiv iab_t \tag{2}$$

where iab_t represents the interest-adjusted basis at time t.

On the basis of the theory of storage, Fama and French (1988) assumed that the (relative) convenience yield[5] is a convex function of the stock level, whereas iab_t is a concave function of the stock level. In particular, at low stock levels, the convenience yield exceeds the storage cost rate (i.e., $y_t > u_t$) and $iab_t < 0$; at high stock levels, the convenience yield falls toward zero, and iab_t increases toward the storage cost rate at a decreasing rate.

Fama and French argued that an implication of the above relation is that a permanent demand shock has a large impact on spot prices when stock levels are low, but a smaller effect on futures prices because the market anticipates future demand and supply responses. Therefore, spot and futures returns should be less correlated when the interest-adjusted basis is negative. Fama and French found evidence in favor of this hypothesis on the basis of the R^2 of regressions of futures returns on spot returns of the LME base metals. In particular, R^2 ranged from 0.96 to 0.99 when the interest-adjusted basis was positive and from 0.77 to 0.92 when the interest-adjusted basis was negative.

3. Measuring association between spot and futures markets

We consider two tests to assess the degree of association between spot and futures markets, depending on the sign of the interest-adjusted basis.[6] The first one is suitable to determine whether two Pearson correlations differ in magnitude statistically. This test is utilized to gauge the difference in correlation between spot and futures returns when the interest-adjusted basis is positive or negative. Based on Fama and French's results, one would expect such correlation to be statistically higher when the interest-adjusted basis is positive. The second test is a Granger causality test which accommodates the existence of cointegration between spot and futures prices. This test is utilized to assess whether feed-back effects between spot and futures prices are stronger when the interest-adjusted basis is positive.

3.1. Difference-in-correlation statistical test

For two random variables, which follow a bivariate normal distribution, the Fisher transformation of their Pearson correlation ($\hat{\rho}$), based on T observations, is approximately normally distributed (e.g., Miller & Miller, 2012, chapter 14):

$$\frac{1}{2}\ln\left(\frac{1+\hat{\rho}}{1-\hat{\rho}}\right) \approx N\left(\frac{1}{2}\frac{(1+\rho)}{(1-\rho)}, \frac{1}{T-3}\right). \tag{3}$$

Under the assumption of two independent samples, T_1 and T_2, expression (3) enables us to device a statistical test under the null hypothesis that the correlations between the spot and futures returns during periods of positive (ρ_1) and negative (ρ_2) interest-adjusted bases are equal:

$$\left(\frac{1}{2}\ln\left(\frac{1+\hat{\rho}_1}{1-\hat{\rho}_1}\right) - \frac{1}{2}\ln\left(\frac{1+\hat{\rho}_2}{1-\hat{\rho}_2}\right)\right) \Big/ \sqrt{\frac{1}{T_1-3} + \frac{1}{T_2-3}} \approx N(0,1) \tag{4}$$

where $\hat{\rho}_1$ and $\hat{\rho}_2$ are the sample Pearson correlation coefficients based on T_1 and T_2 observations, respectively.[7]

3.2. Granger causality test

Testing for linear spillover effects from the futures (spot) log-return to the spot (futures) log-return is based on the concept of Granger causality. In the absence of cointegration between spot and futures prices, the test is based on the following representation:

$$r_t = \delta_0 + B_1\mathbf{r}_{1t} + B_2\mathbf{r}_{2t} + \xi_t \qquad t = 2, \ldots, T \tag{5}$$

where r_t is the log return on the spot (futures) price at time t, $\mathbf{r}_{1t}$ is a vector containing lagged values of r_t and $\mathbf{r}_{2t}$ is a vector containing lagged values of the log return on the futures (spot) price. The number of lags included on the right-hand side of (5) is chosen according to the Schwartz Information Criterion (SIC).[8]

Under the null hypothesis of no feed-back or Granger causality from $\mathbf{r}_{2t}$ to r_t, $\mathbf{B}_2 = \mathbf{0}$. This set of linear constraints is tested by means of an F-statistic of the form $\frac{(\mathbf{C}\hat{\beta}-\mathbf{q})'\left(\mathbf{C}\mathrm{Var}(\hat{\beta}|\mathbf{Z})\mathbf{C}'\right)^{-1}(\mathbf{C}\hat{\beta}-\mathbf{q})}{J} \sim F(J, T-k)$,where $\mathbf{Z}$ is a

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[4] A more recent study on the relationship between convenience yields and stocks is that of Omura et al. (2015), who incorporated geographical location into their analysis.

[5] The relative convenience yield is defined as the ratio of the convenience yield to the spot price.

[6] Fernandez (2016) presents an alternative approach.

[7] It is worth pointing out that Gulley and Tilton's (2014) analysis is based exclusively on a visual inspection of the magnitudes of the correlations between spot and futures returns. No statistical test is provided to assess the correlation difference during contango and backwardation.

[8] It has been shown that SIC is asymptotically consistent with respect to the choice of lag length (see, for instance, Enders, 2010, chapter 2).