# Term Structure of Futures Prices and Expected Mean Reversion in Base Metal Prices

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## Abstract

We examine expected mean reversion in six base metal prices using a unique LME dataset consisting of prices for futures contracts with maturity dates spanning from 1 to 27 months. We document significant evidence of mean reversion in spot prices for all these metals, although the magnitude of mean reversion differs across these markets. We also find that mean reversion in metal prices arises from a positive covariation between spot prices and implied cash flow yields rather from a negative correlation between spot prices and forward interest rates.



**JEL Classification**: G12; G13

**Key words:** Mean reversion; Base metals; LME; Cost-of-carry.


## I. Introduction

There is mounting evidence on mean reversion in financial asset prices (Fama and French, 1988a; Poterba and Summers, 1988; Sweeney, 2000). The resulting predictable pattern in returns has important implications for asset pricing and investment decisions. However, due to the non-availability of reliable spot price data, there has been relatively little evidence on mean reversion in physical asset prices.

In this article, we follow a similar methodology to that of Bessembinder et al. (1995) to examine whether investors anticipate mean reversion in six base metals, namely, primary aluminum, copper, nickel, lead, tin, and zinc, using the LME (London Metal Exchange) price data for futures contracts with delivery dates spanning from 1 to 27 months. Our study departs from the large body of literature on *ex post* return predictability that examines the properties of market-determined prices by focusing on whether investors expect mean reversion to occur in equilibrium. An advantage of using futures price data for contracts with different delivery dates is that it allows us to ascertain the source of mean reversion, subject to the assumption that the cost-of-carry relation holds. This issue has been under debate in the extant asset pricing studies (De Bondt and Thaler, 1985; Fama and French, 1988a; Poterba and Summers, 1988)[2].

We find evidence of expected mean reversion in base metal prices for each market we examine, although the magnitude of mean reversion differs across these markets. There exhibits the greatest degree of mean reversion in copper prices, while the least mean reversion is present in nickel prices. For example, 40% of a copper price shock is expected to revert to its long-run mean over the subsequent year, on average; whereas only 10% of a nickel price shock is reversed. Moreover, we find that the positive covariation between spot prices and implied cash flow yields is the only source of mean reversion for all base metals.

Evidence of mean reversion in these metal prices is important for capital budgeting decisions, storage decisions, and practical trading (hedging) strategies for worldwide metal producers, processors, and dealers, since the LME is a major world market for non-ferrous metals, and LME prices form the basis for trading in physical metals throughout the world[3].

Bessembinder et al. (1995) examine mean reversion using observable term structure of futures prices in broad US futures markets, and find evidence of expected mean reversion in each of

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[2] There are two major views in explaining mean reversion in financial asset prices. Some authors argue that the negative autocorrelations arise from a slowly decaying mean reverting price component, and thus may reflect time varying equilibrium expected returns generated by rational investor behavior (Fama and French, 1988a). Other authors contend that mean reversion in asset prices reflects the temporary divergences of prices from the fundamental value due to irrational trader behavior (De Bondt and Thaler, 1985; Poterba and Summers, 1988).

[3] Another major futures market for non-ferrous metals is the NYMEX in New York. However, NYMEX is confined to trading in copper and aluminum futures contracts only, which are less liquid in terms of trading volume than those on the LME.

these markets. Moreover, they find stronger evidence of mean reversion in agricultural commodities and crude oil markets than in financial asset markets. Fraser and McKaig (1999) follow the methodology of Bessembinder et al. (1995) and explore UK futures term structure data. They find evidence of mean reversion for commodities including aluminum, Brent, gas-oil, and copper. They also report that mean reversion in financial asset prices is present in near rather than distant futures contracts, which differs from the findings of Bessembinder et al. (1995). Although Fraser and McKaig examine base metals in their study, only two metals are included. Moreover, they focus on the mean reverting behavior in base metal prices for only two distant maturity dates (15 and 27 months).

We supplement the evidence on expected mean reversion in base metal prices using the unique LME dataset that consists of prices for futures contracts with maturity dates spanning from 1 to 27 months. The unique trading practice on the LME also offers several advantages in the study of mean reversion in equilibrium asset prices over a standard futures market. First, reliable spot price data are generally unavailable for most physical assets, and therefore nearest maturity futures price is used as a proxy for spot price (Fama and French, 1987; Bessembinder et al., 1995). The use of nearest maturity futures prices can be problematic due to light trading, possible futures squeezes or corners, etc. (Fama and French, 1987)[1]. This problem is resolved using the LME data since both physical metals and futures contracts are traded at the same time on the LME. Second, in a standard futures market there are a limited number of contract maturity dates, and liquidity is focused on a few shorter-term contracts. As a result, prices for longer-term contracts are likely to be unavailable or unreliable. The LME's daily contract structure results in a large number of contracts written with a fixed time to maturity up to 27 months, and the trading of longer-term contracts shows substantial liquidity.

## II. The Cost-Of-Carry Theory and Expected Mean Reversion

The cost-of-carry theory explains the difference between contemporaneous spot and commodity futures prices in terms of carrying charge that is the interest foregone net of implied cash flow yields (convenience yields net of warehousing costs, insurance costs, etc.) to a marginal commodity holder (Working, 1949; Brennan, 1958)[2]. The cost of carry relation can be written as

$$F_t(K) = P_t \cdot e^{(R_{K,t} - C_{K,t})K}, \tag{1}$$

where $F_t(K)$ is the date $t$'s futures price for delivery of a commodity on date $t+K$, $P_t$ is the date $t$'s spot price, $R_{K,t}$ is the continuously compounded interest rate (per period), and $C_{K,t}$ is the implied cash flow yield to a marginal commodity owner, stated as a percentage of the asset price on a continuously compounded basis.

If the cost-of-carry relation holds, mean reversion in equilibrium asset prices has two major testable implications. First, a percentage change in the date $t$'s futures price is less than a percentage change in the date $t$'s spot price. Put differently, the elasticity of futures prices with respect to spot prices is less than unity. Assume that $R_{K,t}$ and $C_{K,t}$ are differentiable functions of spot prices with the first derivatives of $R'$ and $C'$ respectively, then the elasticity of the date $t$'s futures price with respect to the date $t$'s spot price, $\gamma$, is given by

[1] Another problem can arise if we use nearest maturity futures price as a proxy for spot price to study expected mean reversion phenomenon. Since futures prices converge upon spot prices as time approaches maturity, a futures price with longer time to maturity is less accurate as a proxy for the current spot price compared to a futures price with shorter time to maturity. Consequently, the use of futures price as a proxy for spot price would induce noise in the estimation of term slopes.

[2] An alternative theory of commodity futures prices is that a futures price contains two components: a forecast of the future spot price and an expected risk premium (Dusak, 1973). Upon examining the explanatory power of these two competing theories of futures prices using data from broader futures markets, Fama and French (1987) conclude that futures prices appear to reliably respond to carrying cost variables, while there is less convincing evidence that futures prices contain risk premiums or power to forecast future spot prices.

$$\gamma = \frac{\partial F_t(K)}{\partial P_t} \times \frac{P_t}{F_t(K)} = 1 + K * P_t(R'-C') \cdot \quad (2)$$

In equation (2), mean reversion in spot prices requires γ to be less than one. Thus, $R'$-$C' < 0$.

Second, there exists a negative relation between spot prices and the slope of futures term structure, that is, an increase in spot prices is associated with a decrease in the slope of futures term structure, and vice versa. Let $F_t(T)$ be the futures price of the same asset for delivery on date $t + T$, where $T > K$, which can be written as

$$F_t(T) = P_t \cdot e^{(R_{T,t} - C_{T,t})T} . \quad (3)$$

Using equations (1) and (3), we can express the slope of date t's futures term structure over delivery dates $t+K$ to $t+T$, $\beta_{KT,t}$, as

$$\beta_{KT,t} = \frac{LN[F_t(T)/F_t(K)]}{T-K} = R_{KT,t} - C_{KT,t} , \quad (4)$$

where $R_{KT,t}$ and $C_{KT,t}$ are the forward interest rate and implied cash flow yield for the interval from dates $t+K$ to $t+T$ respectively, which are given by

$$R_{KT,t} = \frac{T \times R_{T,t} - K \times R_{K,t}}{T-K} \text{ and} \quad (5)$$

$$C_{KT,t} = \frac{T \times C_{T,t} - K \times C_{K,t}}{T-K} . \quad (6)$$

From equation (4), mean reversion in equilibrium asset prices implies $\frac{\partial \beta_{KT,t}}{\partial P_t} = R_{KT}' - C_{KT}' < 0$. Any detected mean reversion must result either from a negative correlation between forward interest rates and spot prices, i.e., $R_{KT}' < 0$, or from a positive covariation between implied cash flow yields and spot prices, i.e., $C_{KT}' > 0$, or both. Therefore, the assumption on the validation of cost-of-carry relation allows us to ascertain the source of mean reversion, which has been subject to long-lasting debate in the extant asset pricing literature (Fama and French, 1988a; Porterba and Summers, 1988). However, this approach cannot rule out the possibility that mean reversion results from market inefficiency, or investor irrationality.

## III. Data and Methodology

This study analyzes prices of futures contracts for six base metals traded on the LME – primary aluminum, copper, tin, lead, nickel, and zinc – over the January 1993 – January 1997 interval. The unique dataset consists of daily spot and settlement prices for each metal futures contract for delivery dates of 1, 2, 3, 6, 9, 12, 15, and 27 months[1]. These data are obtained from the LME. The sample period is chosen due to the nonavailability of futures prices data for most delivery dates. Two important LME trading practices offer us an interesting opportunity to study expected mean reversion in asset prices: first, the LME's daily contract structure results in a large number of contracts for each metal on a particular trading day (approximately 81 contracts per metal each day)[2]; and second, both spot metals and futures contracts are traded at the same time on the LME. We also collect data on London Inter-bank Offer mid rates (LIBOR) and Eurocurrency Sterling mid rates over the same sample period from Datastream International.

[1] The officially reported prices are confined to delivery periods of 3 months, 6 months, and 12 months only. The data for the 27-month settlement prices for the lead and tin futures are not available, while those for the nickel futures are only available from July 1995 onwards.

[2] The LME contracts have daily prompt dates up to three months ahead, supplemented by a more limited number of longer-term contracts up to 27 months ahead. This implies a new contract is introduced for every trading day.

As discussed in Section II, if spot prices are expected to exhibit mean reverting behavior, the elasticity of futures prices with respect to spot prices is less than one, and declines with the time to maturity. To test this hypothesis, we estimate the elasticity of futures prices with respect to spot prices by regressing the first difference of logarithmic futures prices, $LN[F_t(K)/F_{t-1}(K)]$, on the first difference of logarithmic spot prices, $LN[P_t/P_{t-1}]$, i.e.,

$$LN\left(\frac{F_t(K)}{F_{t-1}(K)}\right)^i = \gamma_0{}^i + \gamma_1{}^i LN\left(\frac{P_t}{P_{t-1}}\right)^i + \varepsilon_t{}^i, \tag{7}$$

where i indicates the *i*th metal futures, $K$ denotes delivery of $K$ periods ahead, and $K$ = 1, 2, 3, 6, 9, 12, 15, and 27 months. If spot prices are mean reverting, the estimated elasticity, $\gamma_1{}^i$, is expected to be less than unity.

Expected mean reversion also implies a negative relation between spot prices and the futures term slope. To detect expected mean reversion in asset prices, we follow the methodology of Bessembinder et al. (1995), and compute the futures term slope, $\beta_{KT,t}$ in equation (4), on the basis of 'nearby' that indicates relative nearness to expiration. For example, 'nearby 1' denotes that the term slope is computed by using the prices of contracts that expire in 1 and 2 months, i.e., $K$=1 and $T$=2, 'nearby 2' indicates that the term slope is computed by using the prices of contracts that expire in 2 and 3 months, i.e., $K$=2 and $T$=3, etc. We regress the futures term slope on spot prices, that is,

$$\beta_{KT,t}{}^i = \lambda_0{}^i + \lambda_1{}^i P_t^i + \eta_t{}^i. \tag{8}$$

If spot prices are mean reverting, the estimated $\lambda_1{}^i$ is expected to be negative. Since both spot prices and futures term slopes are nonstationary, equation (8) is estimated by using the first difference[1]. To allow for comparisons across the markets, each spot price series is scaled using its time series mean.

An advantage of assuming the validation of the cost-of-carry relation is that it allows us to explicitly examine the source of mean reversion. Since there are only two components in the term slope in equation (4): forward interest rate and implied cash flow yield, there are two cases in which mean reversion can occur in equilibrium: first, implied cash flow yields are positively associated with spot prices; and second, forward interest rates covary negatively with spot prices. Thus, we expect that $C'_{KT} > 0$, or $R'_{KT,} < 0$, or both. If $\beta'_{KT} < 0$, along with $C'_{KT} > 0$ and $R'_{KT} = 0$, expected mean reversion results from the positive comovement between implied cash flow yields and spot prices. If $\beta'_{KT} < 0$, along with $R'_{KT} < 0$ and $C'_{KT} = 0$, mean reversion arises from the negative covariation between forward interest rates and spot prices. To empirically test the source of mean reversion, we estimate the first derivatives of implied cash flow yields and forward interest rates with respect to spot prices, $C'_{KT}$ and $R'_{KT}$, by regressing changes in $C_{KT,t}$ and $R_{KT,t}$ on changes in spot prices respectively. We use data on observable term structure of futures prices to obtain estimates of implied cash flow yields using the following formula,

$$C_{KT,t} = R_{KT,t} - \frac{LN[F_t(T)/F_t(K)]}{T-K}. \tag{9}$$

## IV. Empirical Results

Table 1 presents the results of estimating equation (7) for each metal and maturity date. The results indicate that the estimated elasticity is positive and significant at the 1% level for all these metals and maturity dates, indicative of mean reversion in equilibrium spot prices. Moreover, the estimated elasticity decreases monotonically with the time to maturity except for the 3-month

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[1] The results of unit root tests that are not reported (available upon request) fail to reject the existence of unit roots for both spot price and futures term slope series, with a few exceptions for futures term slopes, for example, term slopes for 'nearby 1' primary aluminum, 'nearby 2' primary aluminum, copper, and nickel.

zinc futures. However, the degree of mean reversion differs across these metals. There exhibits a greater degree of mean reversion in copper and lead prices, while the speed of mean reverting is slower in nickel prices. For the copper market, the point estimate for the 12-month futures is 0.597, implying that 40.3% of a copper price shock is reversed over the subsequent year. On the contrary, the estimate for the nickel market is 0.902, suggesting that only about 10% of a nickel price shock is reversed over the subsequent year.

Table 1

Elasticities of distant futures price changes with respect to spot price changes

| | Primary aluminum | Copper | Nickel | Lead | Tin | Zinc |
|---|---|---|---|---|---|---|
| 1-month | 0.9790 (7.78)*** | 0.9061 (16.47)*** | 0.9825 (4.07)*** | 0.8703 (4.82)*** | 0.9327 (6.66)*** | 0.9412 6.46)*** |
| 2-month | 0.9625 (11.72)*** | 0.8517 (20.32)*** | 0.9758 (5.50)*** | 0.8276 (6.39)*** | 0.9168 (8.32)*** | 0.9251 (8.32)*** |
| 3-month | 0.9472 (12.88)*** | 0.7937 (24.27)*** | 0.9533 (9.82)*** | 0.8202 (16.91)*** | 0.9009 (12.92)*** | 0.9600 (10.81)*** |
| 6-month | 0.8890 (15.22)*** | 0.7005 (27.73)*** | 0.9446 (8.90)*** | 0.7016 (20.87)*** | 0.8624 (13.23)*** | 0.8744 (11.96)*** |
| 9-month | 0.8348 (19.90)*** | 0.6403 (30.48)*** | 0.9279 (11.50)*** | 0.6691 (21.77)*** | 0.8417 (14.39)*** | 0.8410 (15.14)*** |
| 12-month | 0.7833 (22.81)*** | 0.5974 (32.21)*** | 0.9021 (13.20)*** | 0.6383 (22.47)*** | 0.8231 (14.99)*** | 0.8091 (17.35)*** |
| 15-month | 0.7436 (18.45)*** | 0.5685 (31.73)*** | 0.8948 (13.04)*** | 0.6641 (21.13)*** | 0.8215 (15.52)*** | |
| 27-month | 0.5945 (20.28)*** | 0.5261 (30.01)*** | 0.8554 (9.40)*** | | | |

This table reports the point estimates of elasticities (equation (4)). The figures in parentheses are *t*-statistics, which are for the hypothesis that the slope coefficient estimate is less than one, and are corrected for heteroskedasticity and autocorrelation based on the Newey-West (1987). Price series are deflated using their time series means. *** , **, and * denote significant at the 1%, 5% and 10% level.

The results of estimating equation (8) are reported in Table 2. The slope coefficient estimate is the point estimate of the first derivative, $\beta'_{KT,t}$. The evidence shows that, consistent with the hypothesis of mean reversion in asset prices, the estimated slope coefficient is negative and significant for all except the 'nearby 6' tin futures (positive and insignificant) and the 'nearby 6' lead and zinc futures. Thus, an increase in spot prices is associated with a decrease in the slope of futures term structure, and vice versa. Note also that the magnitude of estimated coefficients decreases with the time to expiration. However, the coefficient estimate for copper tends to decline faster in magnitude than that for the other metals. This suggests stronger mean reversion anticipated by copper traders than traders in the other metal markets, in line with the previous result. Our findings of expected mean reversion are consistent with those of Bessembinder et al. (1995) and Fraser and Mckaig (1995). These authors document evidence of mean reversion in asset prices in the US and UK respectively.

Tables 3 and 4 present evidence on the source of mean reversion. The risk free rate is proxied by the London Inter-bank Offer mid rate (LIBOR). Table 3 reports the estimate of the derivative of implied cash flow yields with respect to spot prices, $C'_{KT}$. The estimate of $C'_{KT}$ is positive and significant for all these metals, suggesting that the implied cash flow yield sensitivity of spot prices is a reliable source of mean reversion in spot prices. The results of regressing changes in forward interest rates on changes in spot prices are reported in Table 4. The signs of slope coefficient estimates are not uniformly negative, and insignificant. Therefore, it does not appear that the covariation between spot prices and forward interest rates induces mean reversion in metal prices.

Table 2

The slope of futures term structure and the level of spot prices

| | Primary aluminum | Copper | Nickel | Lead | Tin | Zinc |
|---|---|---|---|---|---|---|
| Nearby 1 | -0.3834<br>(-9.85)*** | -1.1583<br>(-16.79)*** | -0.1606<br>(-8.96)*** | -0.7715<br>(-12.51)*** | -0.5101<br>(-12.29)*** | -0.6131<br>(-9.34)*** |
| Nearby 2 | -0.3571<br>(-10.38)*** | -1.0314<br>(-17.25)*** | -0.1533<br>(-4.93)*** | -0.6937<br>(-9.42)*** | -0.4877<br>(-9.60)*** | -0.5986<br>(-5.54)*** |
| Nearby 3 | -0.3447<br>(-10.81)*** | -0.6239<br>(-18.25)*** | -0.1447<br>(-5.37)*** | -0.4695<br>(-10.24)*** | -0.3052<br>(-8.18)*** | -0.5084<br>(-8.27)*** |
| Nearby 4 | -0.3280<br>(-18.32)*** | -0.4007<br>(-18.35)*** | -0.0978<br>(-9.17)*** | -0.1924<br>(-8.47)*** | -0.1279<br>(-9.54)*** | -0.2007<br>(-11.24)*** |
| Nearby 5 | -0.3163<br>(-15.69)*** | -0.2755<br>(-16.44)*** | -0.0938<br>(-9.17)*** | -0.1639<br>(-6.39)*** | -0.1146<br>(-8.05)*** | -0.1906<br>(-10.89)*** |
| Nearby 6 | -0.2466<br>(-4.55)*** | -0.1845<br>(-10.23)*** | -0.0991<br>(-2.28)** | 0.0837<br>(1.38) | -0.0224<br>(-0.32) | 0.0446<br>(1.47) |
| Nearby 7 | -0.2153<br>(-8.12)*** | -0.0678<br>(-6.47)*** | -0.0143<br>(-2.00)** | | | -0.0970<br>(-8.42)*** |

This table reports the estimated coefficients $\lambda_1^i$ in equation (7). 'Nearby 1' denotes results obtained using prices of 1-month and 2-month contracts to compute the slope. 'Nearby 2' denotes results obtained using the prices of 2-month and 3-month contracts. 'Nearby 3' denotes the results obtained using the prices of 3-month and 6-month contracts, etc. To facilitate the comparisons of coefficient estimates, each price series has been divided by its own mean. Regressions are estimated in first differences due to the non-stationary data series. The figures in parentheses are *t*-statistics, which are for the hypothesis that the coefficient estimate is different from zero, and are corrected for heteroskedasticity and autocorrelation based on the Newey-West (1987). *** and ** denote significant at the 1% and 5% level.

Table 3

Implied cash flow yields and the level of spot prices

| | Primary aluminum | Copper | Nickel | Lead | Tin | Zinc |
|---|---|---|---|---|---|---|
| Nearby 1 | 0.3829<br>(9.79)*** | 1.1594<br>(16.81)*** | 0.1612<br>(9.11)*** | 0.7743<br>(12.54)*** | 0.2366<br>(13.25)*** | 0.6175<br>(9.44)*** |
| Nearby 2 | 0.3779<br>(6.39)*** | 1.0350<br>(17.27)*** | 0.1515<br>(7.01)*** | 0.6938<br>(10.42)*** | 0.2109<br>(6.48)*** | 0.6005<br>(6.55)*** |
| Nearby 3 | 0.3409<br>(10.58)*** | 0.6215<br>(18.30)*** | 0.1341<br>(5.30)*** | 0.6693<br>(10.22)*** | 0.1489<br>(5.76)*** | 0.5579<br>(8.21)*** |
| Nearby 4 | 0.3340<br>(18.11)*** | 0.3999<br>(18.06)*** | 0.0967<br>(8.75)*** | 0.1932<br>(9.44)*** | 0.1302<br>(9.12)*** | 0.2024<br>(9.88)*** |
| Nearby 5 | 0.3126<br>(14.85)*** | 0.2756<br>(15.63)*** | 0.0954<br>(8.34)*** | 0.1023<br>(7.02)*** | 0.1103<br>(7.26)*** | 0.1836<br>(9.84)*** |
| Nearby 6 | 0.2911<br>(11.34)*** | 0.2523<br>(14.56)*** | 0.0873<br>(8.21)*** | 0.1004<br>(4.23)*** | 0.1015<br>(6.98)*** | 0.1656<br>(8.33)*** |
| Nearby 7 | 0.2607<br>(9.85)*** | 0.2109<br>(9.63)*** | 0.0678<br>(6.96)*** | | | 0.1589<br>(8.12)*** |

This table reports the estimated coefficient obtained by regressing implied cash flow yields on spot prices. The implied cash flow yield is computed as $C_{KT,t} = R_{KT,t} - \left[LN\left(F_t(T)/F_t(K)\right)/(T-K)\right]$. 'Nearby 1' denotes results obtained using prices of 1-month and 2-month contracts to compute the slope. 'Nearby 2' denotes results obtained using the prices of 2-month and 3-month contracts. 'Nearby 3' denotes the results obtained using the prices of 3-month and 6-month contracts, etc. LIBOR mid rate is used as a proxy for risk free rate. In order to facilitate the comparison of coefficient estimates, each price has been divided by its own time series mean. Regression is estimated in first differences due to the non-stationary data series. The figures in parentheses are *t*-statistics, which are for the hypothesis that the coefficient estimate is different from zero, and are corrected for heteroskedasticity and autocorrelation based on the Newey-West (1987). *** and ** denote significant at the 1% and 5% level.

Table 4

Forward interest rates and the level of spot prices

| | Primary aluminum | Copper | Nickel | Lead | Tin | Zinc |
|---|---|---|---|---|---|---|
| Nearby 1 | -0.0002<br>(-0.07) | 0.0013<br>(0.56) | 0.0013<br>(0.63) | 0.0023<br>(1.04) | 0.0019<br>(0.65) | 0.0046<br>(1.39) |
| Nearby 2 | 0.0007<br>(0.19) | 0.0037<br>(1.16) | 0.0018<br>(0.63) | -0.0006<br>(-0.22) | 0.0028<br>(0.70) | -0.0021<br>(-0.48) |
| Nearby 3 | -0.0040<br>(-1.03) | -0.0029<br>(-0.92) | -0.0007<br>(-0.26) | -0.0004<br>(-0.12) | -0.0023<br>(-0.59) | -0.0009<br>(-0.20) |
| Nearby 4 | 0.0058<br>(139) | -0.0008<br>(-0.23) | -0.0010<br>(-0.31) | 0.0010<br>(0.32) | 0.0032<br>(0.75) | 0.0017<br>(0.35) |
| Nearby 5 | -0.0038<br>(-0.64) | 0.0001<br>(0.02) | 0.0016<br>(0.38) | -0.0045<br>(-1.02) | -0.0045<br>(-0.75) | -0.0078<br>(-1.18) |
| Nearby 6 | 0.0033<br>(0.69) | -0.0009<br>(-0.11) | -0.0010<br>(-0.66) | -0.0030<br>(-0.78) | -0.0098<br>(-0.38) | 0.0059<br>(0.96) |
| Nearby 7 | -0.0058<br>(-1.02) | -0.003<br>(-0.29) | -0.0002<br>(-0.81) | | | -0.0032<br>(-0.87) |

This table reports estimated coefficient obtained by regressing forward interest rates on spot prices. 'Nearby 1' denotes results obtained using prices of 1-month and 2-month contracts to compute the slope. 'Nearby 2' denotes results obtained using the prices of 2-month and 3-month contracts. 'Nearby 3' denotes the results obtained using the prices of 3-month and 6-month contracts, etc. LIBOR mid rate is used as a proxy for the risk free rate. In order to facilitate the comparison of coefficient estimates, each price has been divided by its own time series mean. Regression is estimated in first differences due to the non-stationary data series. The figures in parentheses are *t*-statistics, which are for the hypothesis that the coefficient estimate is different from zero, and are corrected for heteroskedasticity and autocorrelation based on the Newey-West (1987). *** and ** denote significant at the 1% and 5% level.

Our results show that it is $C'_{KT}$ rather than $R'_{KT}$ that is the source of mean reversion in base metal prices, consistent with those of Fraser and McKaig (1999) who find no evidence of negative coefficient estimates for the relevant variables in the forward interest rate regression for aluminum and copper. However, Bessembinder et al. (1995) show that both $C'_{KT}$ and $R'_{KT}$ induce mean reversion in precious metals (silver, gold, and platinum). In conjunction with the evidence in Tables 1 and 2, the coefficient estimate for the recent 'nearby' copper futures is noticeably larger in magnitude than that for other metal futures. This is likely due to the alleged Sumitomo copper manipulations occurred on the LME[1]. Futures manipulations usually result in a situation where short-run supply becomes substantially more inelastic than long-run supply, or more volatile convenience yields to marginal copper holders (backwardations) (Fama and French, 1988b). Therefore, when spot prices increase, there exists a larger increase in implied cash flow yields, resulting in stronger mean reversion in prices.

[1] It is alleged that Sumitomo Corporation intermittently manipulated the world copper market mainly operated on the LME copper futures market over the period of 1993-1996, which caused notice and resulted in inquiries initiated by the Securities and Investment Board (SIB) and the Commodity Futures Trading Commission (CFTC) at the end of 1995. The manipulation scheme failed due to fierce attack by a hedge fund in June 1996, resulting in copper prices falling from $2,700/tonne to below $2,000/tonne. For an analysis of the effect of silver manipulations on the forward/futures – spot relations, see Fama and French (1988b).

## V. Conclusions

In this paper, we examine mean reversion in equilibrium base metal prices using the term structure of futures prices at which contracts are traded on the LME. We find evidence of mean reversion in each of the six base metals – primary aluminum, copper, nickel, lead, tin, and zinc. The estimated elasticity of distant futures prices with respect to spot prices is less than unity for all metals and delivery dates. We also find a negative relation between spot prices and futures term slope, although the magnitude of mean reversion differs across these metals. There exhibits the greatest degree of mean reversion in copper prices, with 40% of a price shock to be reversed in the subsequent year, on average; whereas the least degree of mean reversion presents in nickel prices, with only about 10% of a price shock to be reversed.

If the no arbitrage cost-of-carry relation holds, expected mean reversion can arise from the covariation between spot prices and implied cash flow yields, and/or the correlation between spot prices and forward interest rates. Our empirical evidence shows that, similar to the findings in Fraser and McKaig (1999), mean reversion in all base metal prices stems solely from the implied cash flow yield sensitivity of spot prices.

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