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# Reexamining the maturity effect using extensive futures data;

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**Reexamining the Maturity Effect Using Extensive Futures Data**

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*Abstract*

In his seminal article, Samuelson (1965) proposes the maturity effect that volatility of futures prices should increase as futures contract approaches expiration. This study provides new evidence on the maturity effect by examining a more extensive set of futures contracts over longer period than previous studies: 8451 futures contracts drawn from 74 commodities and four International exchanges, (London, Sydney, Tokyo and Winnipeg Futures), in addition to the U.S. markets over the years from 1960 to 2000. Strong support is found for the maturity effect in agricultural and energy commodities, but not for financial futures. Moreover, negative covariance between spot price and net carry cost appears to be able explain the maturity effect fairly well for commodity futures.

## I. Introduction

The hypothesis that price variability increases as time-to-maturity nears, first proposed by Samuelson (1965), has important implications on the behavior of futures prices. The relation between volatility and maturity also has implications for margin setting and hedging strategy. The desired margin size is a positive function of futures price volatility. Therefore, if volatility increases as delivery approaches, margins should also increase near maturity. In addition, rising volatility near delivery suggests that correlation between spot and futures prices is weakened. Consequently, hedging strategies should be adjusted as maturity approaches. Finally, since volatility is one of the factors determining the price of an option, a better feel for the maturity effect provides insights for pricing of options on futures.

This study attempts to shed new light on the maturity effect by examining a more extensive set of futures contracts and longer period than previous studies. Specifically, we utilize data of 8451 futures contracts drawn from 74 commodities and from four International exchange markets (London, Sydney, Tokyo and Winnipeg Futures), in addition to the U.S. markets over the years from 1960 to 2000. Furthermore, in contrast to most extant literature that uses constructed time series, we analyze each contract individually, thereby utilizing the full extent of the data. Ma, Mercer and Walker (1992) suggest that aggregating contracts can distort empirical results. In reporting the results, we focus on the percentage of contracts that is consistent with the maturity effect, which has the added advantage that overall conclusions are not affected by extreme estimates. Last but not least importantly, we provide an analysis of the role of covariance between changes in spot prices and carry costs in explaining the maturity effect. Bassembinder, Coughenour, Seguin and Smeller (1996) show that if this covariance is negative, the maturity effect is likely to exist. Nevertheless, their empirical analysis does not directly link covariance of prices and carry costs with the maturity effect, as in this study. Furthermore, our sample is much greater than theirs.

Our primary results indicate that, on average, 45% of the agricultural contracts confirm the maturity effect, and, more importantly, the maturity effect is present in around 80% of contracts that have negative covariances. For currencies futures contracts, the covariance hypothesis has much less power in explaining the maturity effect.

The paper is organized as the follows. The next section presents a brief review of related literature. This is followed by a discussion of methodology and the data. In the fourth section, the empirical results are reported. The paper ends with a summary and conclusions

## II. Related Literature

Samuelson (1965) was the first to suggest that price volatility should increase as futures expiration approaches. However, his analysis gives neither formal proofs nor conditions for what has come to be known as the Samuelson hypothesis. Anderson and Danthine (1983) reinterpret the maturity effect by incorporating time variation in the rate of information flow. They believe that there is no inherent tendency for price volatility to increase as delivery approaches; the underlying reason may be the rate of information flows. Specifically, their hypothesize that the maturity effect reflects more uncertainty resolved or more information flows into the market near maturity.

A more recent theoretical analysis is introduced by Bassembinder, Coughenour, Seguin and Smeller (1996) (BCSS, thereafter), in which they develop a framework to predict markets in which the maturity effect should be expected to hold. They show that "neither the clustering of information flows near delivery dates nor the assumption that each futures price is an unbiased forecast of delivery date spot prices is a necessary condition for the success of the hypothesis." Specifically, they assume the cost of carry model as follows.

$$F_t = S_t e^{c\tau} \quad (1)$$

where F is the futures price, S is the spot price, τ is time-to-maturity, c is the net cost of carry, and *c* = *r-y,* where r is the risk-free rate and y is the convenience yield. Given Equation (1), they demonstrate that

$$\begin{aligned} Ln(F_t) &= Ln(S_t) + c\tau \\ \sigma_F^2 &= \sigma_S^2 + \tau^2\sigma_c^2 + 2\tau Cov(c, Ln(S_t)) \end{aligned} \quad ..(2)$$

where $\sigma_F^2$ is the variance of futures; $\sigma_S^2$ is the variance of spot; $\sigma_c^2$ is the variance of the net carry cost (which is reflected by futures term structure); and $Cov(c, Ln(S_t))$ represents the covariance between changes in spot prices and net carry costs. They point out that greater spot volatility near maturity should affect all contracts (including short-term and long-term contracts), thus implying saw-tooth patterns in volatility for longer-term futures. Given that futures prices do not exhibit such a pattern, variation in the spot price volatility is ruled out as an explanation for the maturity hypothesis. If $\sigma_c^2 > 0$ and is constant, reduction in $\tau^2$ over time will cause futures volatility to drop as delivery approaches, which is contrary to the maturity effect. Therefore this is also rejected as a potential explanation for the maturity effect by BCSS. Only the last term can have a positive or negative effect on futures volatility. They therefore hypothesize that the maturity effect should exist when the covariance between net carry cost and the spot price is sufficiently negative to outweigh the positive effect of $\tau^2\sigma_c^2$. Thus, the BCSS model predicts that maturity effect will tend to hold when the covariance is negative. They also argue that real assets most likely have negative covariance, since covariance between prices and convenience yields of real assets is often positive. For instance, Fama and French (1988) argue that reductions in real asset inventories around business cycles peaks would be associated with both increased convenience yields and spot prices. Positive covariance between prices and yields can also come from seasonality in production or consumption. Similar arguments for financial assets would be weaker, since it is difficult to postulate either substantial time series variation in asset inventory or the importance of convenience yields for financial assets. Therefore, the BCSS model argues that the maturity effect is less likely to hold in financial assets, a prediction seems somewhat supported by the cumulative evidence, as summarized below.

In general, empirical evidence regarding the maturity effect is mixed, but the effect seems to be stronger in non-financial futures than in financial. The remainder of this section provides a brief review of empirical studies on the issue.

Rutledge (1976) studies March 1970 Silver contract, December 1970 cocoa contract, September 1969 wheat contract and May 1971 soybean oil contract. Using daily price observation expressed in logarithms and taking the absolute value of prices differences as a measure of volatility, he employs a goodness of fit test for a three-way contingency table. His results reject the maturity effect for wheat and soybean oil but accept it for silver and cocoa. Dusak-Miller (1979) investigates the maturity effect using June and December live cattle futures contracts for the period 1964-1972. She computes correlation coefficients between volatility and time to maturity and concludes a significant negative relationship, thus supporting the

Samuelson hypothesis. Castelino and Francis (1982) test the maturity effect using daily data from 1960 to 1971 for futures on wheat, corn, soybeans, soybeans meal, soybean oil, and copper. Their methodology standardizes the variance by dividing by the geometric mean of the sample variances of all contracts within the same month of observation. The study employs two tests: the test of equality of the average standardized variances and the significance of the time-to-maturity coeffficient in the OLS regression of standardized variance on time-to-maturity; the results largely support the maturity effect. Anderson (1985) uses both nonparametric and parametric tests and indicates significant maturity effects for oats, soybean oil, live cattle, and cocoa but no such effect for wheat, corn, soybeans, or silver, for the sample period of 1966-1980.

Several studies also cover interest-rate sensitive futures. Milonas's (1986) examines wheat, corn, soybeans, soybean meal, soybean oil, GNMA, T-bonds, T-bills, copper, gold, and silver contracts for the period 1972-1983. His empirical evidence is consistent with the maturity effect in 10 out of the 11 futures he analyzes. Grammatikos and Saunders (1986) find no relation between volatility and time-to-maturity for currency futures prices. Barnhill, Jordan, and Seal (1987) document evidence supportive of a maturity effect in the Treasury bond futures market during the period 1977-1984.

The maturity effect in stock index futures is analyzed by Chamberlain (1989), Board and Sutcliffe (1990) and Yang and Brorsen (1993); their results in general are weakly consistent with the maturity effect.

Galloway and Kolb (1996) examine a comprehensive data set, including 45 commodities over the period 1969 to 1992. After controlling for sources of nonstationary other than maturity, the time to maturity variable is found to have a significant negative relationship to monthly return variance for many of the agricultural commodities, for all energy commodities, and for copper. In contrast, time to maturity is not a significant factor for the precious metals and for all but one of the financials commodities. BCSS (1996) also empirically analyze 11 commodities over roughly a 10-year period. They find that the maturity effect tends to be resent in agriculturals but not in financials. Nevertheless, their empirical analysis does not directly link covariance of prices and carry costs with the maturity effect, as in this study. Additionally, the sample here is more extensive than theirs; we include virtually the universe of futures contracts.

## III. Data and Methodology

The data in this study consists of daily open, high, low, close, volume and open interest for futures contracts that expired during the years 1960 through 2000. The data is obtained from the R & C Research financial price database, a commercial vendor of futures data. Over 2,300,000 daily prices are available for 8451 futures contracts on 74 commodities, covering the major international exchange markets. Table I provides descriptive information for each commodity, including the beginning year of futures price data, the number of contracts and the expiration months of the futures contact.

As shown in Table I, agricultural commodities represent 47% of the sample contracts, energy and metals commodities represent 22.5%, and financial commodities account for the remaining 30.5% of the sample contracts. Agricultural commodities contracts account for the largest portion of our sample due to the longer history of theses contracts. For instance, wheat and soybean futures have been traded since 1960. In contrast, the introduction dates are mid 70's for currency futures, early 80's for energies futures, late 80's for financials futures, and mid 80's for index futures.

In addition to the U.S. futures markets, our data set contains 20 futures contracts drawn form four international exchange markets (London, Sydney, Tokyo and Winnipeg). This data is more comprehensive than previous studies in three manners: longer period of time coverage (almost full coverage from the time prospective), a larger number of futures contracts and coverage of international futures exchanges.

The maturity effect is investigated by performing the following ordinary least square regression, for each individual contract.

$$\sigma^2_{j,t} = \beta_0 + \beta_1 \tau_{j,t} + \varepsilon_t \qquad ..(3)$$

where $\sigma^2_{j,t}$ represents price volatility; $\tau$ is the number of days until maturity; The main hypothesis and focus is that if the maturity effect exists, the coefficient of $\tau$ is negative.

The majority of empirical studies create a time series by linking price changes or returns from separate futures contracts. This requires choosing the time to switch from the nearby contract to the next nearby contract, and adjusting for any differences in price level between the two contracts. Ma, Mercer and Walker (1992) point out that the manner in which the price series are linked can have unpredictable effects on the results of empirical studies. Due to problems and pitfalls of linking price series, methodologies that avoid this are preferable, such as a separate analysis for each contract. Therefore, in this study, we analyze each contract individually. Another reason for this approach is that it will utilize the full information provided by the data. Thousands of contracts need to be analyzed and it is difficult to summarize the results. Therefore, we focus on the percentage of contracts that is consistent with the maturity effect; this has the added advantage that overall conclusions are not affected by extreme regression coefficients.

As in most studies that deal with the maturity effect, the basic unit of observation is the logarithm of daily futures price. The main reason for working with the log differences is that as price level would change we would expect the dispersion of prices to change in the same direction; using percentage changes or log differences corrects for this obvious source of nonstationarity. As a measure of volatility, we employ the classical estimator of price relatives' logarithm. More specifically, the price relative change is calculated as the logarithm of relative daily prices from day t-1 to day t.

$$f_{jt} = Ln(\frac{F_{j,t}}{F_{j,t-1}}) \quad ..(4)$$

where $F_{j,t}$ is the closing price for futures contract $j$ on day $t$ . The volatility of daily price relative for contract $j$ calculated as

$$\sigma^2_{j,t} = (Ln(\frac{F_{j,t}}{F_{j,t-1}}))^2 \quad ..(5)$$

To test BCCS (1996) hypothesis, we follow Bassembinder, Coughenour, Seguin, and Smeller (1995), in which the net carry cost is estimated on a daily basis as the following.

$$c_{,j,t} = \frac{Ln(F_{j,t}) - Ln(S_{j,t})}{\tau} \quad ..(6)$$

Then the following regression is run to infer the covariance sign between the spot and net carry cost.

$$c_{j,t} = \alpha_0 + \alpha_1 Ln(S_{j,t}) + \varepsilon_t \qquad ..(7)$$

where $c_{j,t}$ is the net carry cost for contract j in day t and $S_t$ is the spot price at time t.

If the maturity effect tends to be stronger for contracts that have negative covariance, it would provide support for the BCSS hypothesis.

## IV. Empirical Results

Table II presents the summary result of the OLS regression for each commodity. The first column indicates the number of contracts tested. The third column reports the percentage of contracts that is consistent with the maturity effect ($\beta_1 < 0$ at the 95% confidence level) while the fourth column shows the percentage of contracts that contradicts the maturity effect ($\beta_1 > 0$). Examining the percentage of contracts that have significant maturity effect ($\beta_1 < 0$) reveals that, on average, 45.66% of agricultural commodities show significant maturity effect. For example, 63% of the Lean Hogs, 37% of Corn, 44.5% of COBT Wheat, and 54% of Wheat traded in London demonstrate significant maturity effects. For Energy futures, 54.4% of the contracts tested have significant maturity effect; it is the highest for Natural Gasoline, where 89.6% confirm the existence of the maturity effect, and the lowest for Propane Gas, 37%. On average, 32.2% of Metal futures confirm the existence of the maturity effect; the highest percentage is recorded for Copper, where 41.2% of contracts have significant maturity effects. For these commodity futures, few contradict the maturity effect, especially for commodities that are likely to have high convenience yields.

Index and interest-rate futures in general show a weak maturity effect: 13.8% of the contracts tested. It is the lowest for 30-day interest rate futures (0%) and the highest for U.S. Treasury Composite (38.2%). Moreover, the percentage of interest-rate futures that show decreasing variance near maturity is relatively high: 31.1%. Similar results are found for currency futures. Overall, the results in Table II are in agreement with the conclusion from previous studies that the maturity effect tends to be more pronounced in non-financials commodity futures than financials. This conclusion remains qualitatively the same when we pool all contracts and control for the year and month effects, as shown in the appendix.[1]

To examine BCCS (1996)'s hypothesis, we estimate covariance between net carry costs and spot prices. Spot prices for currencies are readily available, thus we use currency futures as a representative for financial futures. On the other hand, spot prices are unavailable for most commodities. We use agricultural contracts as representatives for non-financials, where nearby futures prices are employed as proxies for spot prices (Fama and French (1988)). These covariance estimates are displayed in Table III.

The third and fourth columns of Table III report the percentage of contracts showing a negative and positive covariance, respectively. The fifth column shows the percentage of contracts that have negative covariance out of all contracts that exhibit maturity effect. The sixth column reports the percentage of contracts that have positive covariance out of all contracts that demonstrate decreasing volatility. The results in Table III in general suggest that for contracts where convenience

[1] In addition to the maturity effect, several sources of nonstationarity in futures prices have been identified in the literature. As described in Milonas (1986), the year effect refers to year-to-year variability in futures prices due to random shocks, such as weather conditions or political events. The calendar-month effect refers to seasonality within a year of the demand for or supply of the commodity. For example, for many agricultural commodities, price volatility increases during summer months when information on changing weather conditions has the most effect on expectation about crop supply. On the other hand, for energy commodities, production may not be very seasonal, but demand exhibits strong seasonality.

yields are present, covariances between net carry cost and the spot price are negative. On average, 81% of agricultural commodities show negative covariance. Whereas for contracts whose convenience yields are low, such as financial futures, the percentages of negative and positive covariances are roughly the same. For the BCSS hypothesis to hold, the majority of the agricultural contacts should exhibit the maturity effect. Indeed, the results show that on average 45% of the agricultural contracts confirm the maturity effect, and, more importantly, the maturity effect is present in around 80% of contracts that have negative covariances. For currencies futures contracts, the covariance hypothesis has much less power in explaining the maturity effect; only 35% out of all contracts having negative covariance exhibit maturity effect. In summary, Table III suggests that the BCSS model can explain the maturity effect fairly well for agricultural futures but not for currency futures.

**V. Summary and Conclusions**

This paper re-examines the maturity effect, a source of nonstationarity in futures prices. The data includes 2,300,000 daily prices from the period 1960-2000, for 8451 contracts on 74 commodities and 4 International exchange markets, (London, Sydney, Tokyo and Winnipeg Futures) in addition to the U.S. exchanges. The contracts analyzed are drawn form both physical (agricultural, energy and metals) and financials (stock index, interest rate and currency) commodities.

Our general results are that the maturity effect tends to be stronger for commodity contracts, compared to financial futures. Moreover, (negative) covariance between spot price and net carry cost appears to be able explain the maturity effect fairly well for commodity futures.

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## *Appendix*

The dependent variable is the daily volatility. The independent variables are the time to maturity and dummies for calendar months and years.

$$\sigma^2_{j,t} = \beta_1 \tau + \sum_{i=1}^{12} \alpha_i C_{i,j,t} + \sum_{y_0}^{y_t} \lambda_y y_{j,t} + \varepsilon_i$$

| Commodity Type | Maturity Effect $\beta_1$ | $t_B$ | Year Effect H₀: $\lambda_y = 0 \ \forall y_i$ F-statistics | Calendar Month Effect H₀: $\alpha_i = 0 \ \forall i$ F-statistics | $R^2$ |
|---|---|---|---|---|---|
| **Agricultural** | | | | | |
| Soybean Oil | -0.0000006174 | -6.24** | 42.12** | 25.63** | .373 |
| Soybeans | -0.0000004350 | -5.21** | 45.23** | 47.50** | .429 |
| Soybean Meal | -0.0000016097 | 10.69** | 62.23** | 31.23** | .421 |
| Corn | -0.0000001216 | -1.40 | 23.5** | 2415** | .200 |
| Oats | -0.0000009420 | -7.43** | 21.50** | 30.10** | .346 |
| Oats (Winnipeg) | -0.0000000566 | -2.38* | 2.79* | 2.66* | .277 |
| Wheat | -0.0000006231 | -5.02** | 33.87** | 15.70** | .352 |
| Wheat (Kansas City) | -0.0000002791 | -1.63 | 13.95** | 10.5** | .178 |
| Wheat (London) | -0.0000005362 | -4.41** | 5.87** | 2.16* | .273 |
| Cocoa | 0.0000066075 | 0.20 | 2.11* | 1.87* | .107 |
| Frozen Orange Juice | -0.0000003421 | -12.14** | 27.64** | 54.23** | .361 |
| Coffee | -0.0000020058 | -4.12** | 16.25** | 1312** | .273 |
| Coffee (London) | -0.0001870604 | -1.96* | 4.60** | 3.56** | .233 |
| Rough Rice | -0.0000004995 | -3.68** | 22.56** | 8.94** | .280 |
| Sugar #14 | -0.0000002133 | -6.80** | 9.31** | 3.46** | .223 |
| Cotton #2 | -0.0000007663 | -6.51** | 22.44** | 16.56** | .224 |
| Lumber | -0.0000008224 | -8.51** | 21.58** | 17.45** | .298 |
| Barley (London) | -0.0000005130 | -2.63* | 2.79** | 4.60** | .246 |
| Potatoes (London) | -0.0000366158 | -4.05** | 2.21** | 2.25** | .229 |
| Sugar #5 (London) | | | | | |
| Rapeseed (Winnipeg) | -0.0000004401 | -4.60** | 14.01** | 14.59** | .283 |
| Feeder Cattle | -0.0000001004 | -7.09** | 32.21** | 25.41** | .423 |
| Live Cattle | -0.0000003879 | -8.12** | 41.28** | 25.61** | .436 |
| Lean Hogs | -0.0000002973 | -16.21** | 17.41** | 6.32** | .317 |
| **Energy** | | | | | |
| Crude Oil | -0.0000027685 | -5.5** | 12.3** | 10.2** | 0.439 |
| Heating Oil | -0.0000002077 | -5.7** | 34.1** | 29.0** | 0.419 |
| Unleaded Gasoline | -0.0000016821 | -6.0** | 13.0** | 17.2** | 0.481 |
| Natural Gasoline | -0.0000067570 | -19.3** | 23.5** | 21.5** | 0.828 |
| Propane Gas | -0.0000022522 | -3.6** | 11.3** | 21.3** | 0.446 |
| **Metals** | | | | | |
| Gold | -0.000000156 | -3.38** | 32.27** | 51.20** | 0.199 |
| High Grade Copper | -0.000000155 | -19.75** | 21.25** | 31.02** | 0.225 |
| Palladium | -0.000000116 | -1.818 | 44.32** | 32.25** | 0.182 |
| Silver | -0.000000071 | -2.94** | 18.94** | 12.53** | 0.179 |

Appendix (continued)

| **Commodity Type** | Maturity Effect | | Year Effect<br>H$_0$: $\lambda_y = 0$ ∀y$_i$ | Calendar Month Effect<br>H$_0$: $\alpha_i = 0$ ∀i | |
|---|---|---|---|---|---|
| | $\beta_1$ | $t_B$ | F-statistics | F-statistics | $R^2$ |
| **Stock Index** | | | | | |
| Eurotop-100 Index | 0.0002758593 | 1.44 | 1.99* | 1.65 | 0.081 |
| Municipal Bonds | 0.0000001086 | 3.75** | 18.01** | 1.83 | 0.095 |
| S&P 400 Mid Cap Index | -0.00000 0282 | -0.18 | 6.69** | 1.75 | 0.075 |
| 3-Month Can. Bankers Acc | 0.0000000053 | 2.49 | 6.25** | 1.77 | 0.055 |
| Nikkei 225 Stock Index | -0.0000000209 | -0.375 | 4.02** | 2.30 | 0.099 |
| Russell 2000 | -0.0000000108 | -0.70 | 10.05** | 1.80 | 0.045 |
| S&P 500 Index | 0.0000007314 | 0.23 | 14.12** | 4.63** | 0.089 |
| NY Stock Composite Index | 0.0000015558 | 2.75** | 2.94** | 1.74 | 0.097 |
| All Ordinary Index | 0.0000013461 | 2.28* | 1.64 | 0.88 | 0.057 |
| Tokyo Stock Price Index | 0.0000013410 | 3.76** | 6.23** | 0.78 | 0.065 |
| FTSE 100 Index | 0.0000002789 | 0.96 | 3.22** | 0.90 | 0.045 |
| **Interest Rate** | | | | | |
| Eurodollar | 0.000000032 | 0.57 | 5.25** | 1.40 | 0.091 |
| Libor (1 Month) | 0.000000006 | 1.95 | 7.50** | 3.90** | 0.102 |
| 30-day Interest Rate | 0.000000002 | 0.23 | 3.25** | 1.42 | 0.062 |
| Five Year Treasury Note | 0.000000044 | 0.70 | 2.40** | 0.60 | 0.022 |
| Three Month T-Bills | 0.000001812 | 0.40 | 1.13 | 1.50 | 0.070 |
| Ten Year Treasury Note | 0.000000163 | 0.97 | 11.45** | 1.25 | 0.046 |
| US Treasury Composite | 0.000000175 | 0.46 | 22.5** | 6.21** | 0.048 |
| Australian 10 Year Bond | -0.000000007 | -0.58 | 6.12** | 1.05 | 0.133 |
| Australian 3 Year Bond | -0.000000004 | -0.27 | 7.50** | 1.78 | 0.073 |
| Japanese 10 Yr Gov. Bond | 0.000000045 | 0.31 | 9.18** | 1.68 | 0.148 |
| **Currencies** | | | | | |
| Australian Dollar | 0.0000000402 | 1.02 | 12.2* | 1.7 | 0.400 |
| British Pound | 0.0000001327 | 4.27* | 21.0* | 1.1 | 0.450 |
| Canadian Dollar | 0.0000000143 | 2.13* | 11.1* | 10.4** | 0.420 |
| German Mark | -0.0000000044 | -0.22 | 12.5* | 4.5* | 0.460 |
| Dollar Index | -0.0000000068 | -0.33 | 11.2* | 3.7* | 0.470 |
| French Franc | -0.0000000078 | -0.71 | 9.3* | 4.3* | 0.440 |
| Japanese Yen | 0.0000000068 | 0.71 | 14.2* | 6.2* | 0.360 |
| Swiss Franc | 0.0000000055 | 0.81 | 22.5* | 21.1** | 0.480 |

Table I
Descriptive Information on Sample
(Data goes to Dec 2000)

| Ticker | Commodity | Starting Date | Number of Contracts | Contracts Months |
|---|---|---|---|---|
| | | **Currencies** | | |
| AD | Australian Dollar | 1987 | 56 | 3,6,9,12 |
| BP | British Pound | 1975 | 104 | 3,6,9,12 |
| CD | Canadian Dollar | 1977 | 96 | 3,6,9,12 |
| DM | German Mark | 1975 | 104 | 3,6,9,12 |
| DX | Dollar Index | 1986 | 60 | 3,6,9,12 |
| FR | French Franc | 1993 | 32 | 3,6,9,12 |
| JY | Japanese Yen | 1977 | 96 | 3,6,9,12 |
| SF | Swiss Franc | 1975 | 104 | 3,6,9,12 |
| | | **Energies** | | |
| CL | Crude Oil | 1983 | 216 | 1,2,3,4,5,6,7,8,9,10,11,12 |
| HO | Heating Oil | 1979 | 264 | 1,2,3,4,5,6,7,8,9,10,11,12 |
| HU | Unleaded Gasoline | 1985 | 192 | 1,2,3,4,5,6,7,8,9,10,11,12 |
| NG | Natural Gasoline | 1990 | 132 | 1,2,3,4,5,6,7,8,9,10,11,12 |
| PN | Propane Gas | 1987 | 168 | 1,2,3,4,5,6,7,8,9,10,11,12 |
| | | **Financials** | | |
| ED | Eurodollar | 1982 | 76 | 3,6,9,12 |
| EM | Libor (1 Month) | 1990 | 132 | 1,2,3,4,5,6,7,8,9,10,11,12 |
| FF | 30-day Interest Rate | 1988 | 52 | 3,6,9,12 |
| FV | Five Year Treasury Note | 1988 | 52 | 3,6,9,12 |
| TB | Three Month T-Bills | 1976 | 100 | 3,6,9,12 |
| TY | Ten Year Treasury Note | 1982 | 76 | 3,6,9,12 |
| US | US Treasury Composite | 1977 | 96 | 3,6,9,12 |
| | | **Foods** | | |
| CC | Cocoa | 1960 | 205 | 3,5,7,9,12 |
| JO | Frozen Orange Juice | 1967 | 204 | 1,3,5,7,9,11 |
| KC | Coffee | 1973 | 168 | 3,5,7,9,11,12 |
| NR | Rough Rice | 1986 | 90 | 1,3,5,7,9,11 |
| SB | Sugar #11 | 1961 | 240 | 1,3,5,7,9,10 |
| SBF | Sugar #14 | 1993 | 48 | 1,3,5,7,9,11 |
| | | **Grains** | | |
| BO | Soybean Oil | 1960 | 369 | 1,3,5,7,8,9,10,11,12 |
| C | Corn | 1960 | 205 | 3,5,7,9,12 |
| KW | Wheat (Kansas City) | 1976 | 125 | 3,5,7,9,12 |
| O | Oats | 1960 | 205 | 3,5,7,9,12 |
| S | Soybeans | 1960 | 287 | 1,3,5,7,8,9,11 |
| SM | Soybean Meal | 1960 | 369 | 1,3,5,7,8,9,10,11,12 |
| W | Wheat | 1960 | 205 | 3,5,7,9,12 |

Table I (continued)

| Ticker | Commodity | Starting Date | Number of Contracts | Contracts Months |
|---|---|---|---|---|
| | | **Metals/Fiber** | | |
| CT | Cotton #2 | 1960 | 205 | 3,5,7,10,12 |
| GC | Gold | 1975 | 156 | 1,2,3,4,6,8,10,12 |
| HG | High Grade Copper | 1960 | 205 | 1,3,5,7,9,10,12 |
| LB | Lumber | 1973 | 168 | 1,3,5,7,9,11 |
| PA | Palladium | 1977 | 96 | 3,6,9,12 |
| PL | Platinum | 1968 | 132 | 1,4,7,10 |
| SI | Silver | 1964 | 185 | 1,3,5,7,9,12 |
| | | **Index Based Items** | | |
| CR | CRB Index | 1986 | 90 | 1,2,4,6,8,11 |
| ET | Eurotop-100 Index | 1992 | 36 | 3,6,9,12 |
| GSCI | GS Comm Index | 1992 | 108 | 1,2,3,4,5,6,7,8,9,10,11,12 |
| MB | Municipal Bonds | 1985 | 64 | 3,6,9,12 |
| MD | S&P 400 Mid Cap Index | 1992 | 36 | 3,6,9,12 |
| BAX | 3-Month Can. Bankers Acc | 1994 | 28 | 3,6,9,12 |
| NK | Nikkei 225 Stock Index | 1990 | 44 | 3,6,9,12 |
| RU | Russell 2000 (day) | 1993 | 32 | 3,6,9,12 |
| SP | S&P 500 Index | 1982 | 76 | 3,6,9,12 |
| YX | NY Stock Composite Index | 1983 | 72 | 3,6,9,12 |
| | | **Meats** | | |
| FC | Feeder Cattle | 1974 | 216 | 1,3,4,5,8,9,10,11 |
| LC | Live Cattle | 1965 | 216 | 2,4,6,8,10,12 |
| LH | Lean Hogs | 1970 | 217 | 2,4,6,7,8,10,13 |
| PB | Pork Bellies | 1966 | 175 | 2,3,5,7,8 |
| | | **International Markets** | | |
| | | **London Markets** | | |
| LBR | Barley | 1994 | 35 | 1,3,5,9,11 |
| LKC | Coffee - Metric | 1993 | 48 | 1,3,5,7,9,11 |
| LES | Euro/Swiss Franc | 1992 | 36 | 3,6,9,12 |
| LFX | FTSE 100 Index | 1984 | 68 | 3,6,9,12 |
| LCC | London Metric Cocoa | 1993 | 40 | 3,5,7,9,12 |
| LFG | Long Gilt (20 Year) | 1990 | 44 | 3,6,9,12 |
| LPO | Potatoes | 1994 | 35 | 3,4,5,6,11 |
| LFL | Short Sterling (3 Month) | 1984 | 68 | 3,6,9,12 |
| LSB | Sugar #5 | 1993 | 40 | 3,5,8,10,12 |
| LW | Wheat | 1994 | 42 | 1,3,5,7,9,11 |
| LEC | Three Month Euro Curr Unit | 1991 | 40 | 3,6,9,12 |

Table I (continued)

| Ticker | Commodity | Starting Date | Number of Contracts | Contracts Months |
|---|---|---|---|---|
| | | **Sydney Futures** | | |
| AAO | All Ordinary Index | 1991 | 40 | 3,6,9,12 |
| ASX | Australian 10 Year Bond | 1992 | 36 | 3,6,9,12 |
| ASY | Australian 3 Year Bod | 1992 | 36 | 3,6,9,12 |
| | | **Tokyo Futures** | | |
| BT | Japanese 10 Yr Govt Bond | 1992 | 36 | 3,6,9,12 |
| IT | Three Month Euro yen | 1992 | 36 | 3,6,9,12 |
| TTX | Tokyo Stock Price Index | 1992 | 36 | 3,6,9,12 |
| | | **Winnipeg** | | |
| WO | Oats | 1992 | 45 | 3,5,7,10,12 |
| WR | Canola Rapeseed | 1981 | 100 | 1,3,6,9,11 |
| WW | Wheat | 1980 | 105 | 3,5,7,10,12 |

Futures months Symbols
1=F, 2=G, 3=H, 4=J, 5=K, 6=M, 7=N, 8=Q, 9=U, 10=V, 11=X, 12=Z

Table II
Percentage of Contracts consistent with the Maturity Effect

The dependent variable is daily volatility. The independent variable is the time to maturity. The third column reports the percentage of contracts with significant maturity effect at 95% confidence. The fourth column reported the percentage of contracts that contradict the maturity effect.

$$\sigma^{2}_{j,t} = \beta_0 + \beta_1 \tau_{j,t} + \varepsilon_t$$

| Commodity | Number of Contracts | $\beta_1 < 0$ | $\beta_1 > 0$ |
|---|---|---|---|
| **Agricultural** | | | |
| Soybean Oil | 319 | 39.50% | 8.46% |
| Soybeans | 278 | 43.17% | 15.07% |
| Soybean Meal | 320 | 48.13% | 13.75% |
| Corn | 195 | 36.92% | 17.43% |
| Oats | 230 | 42.61% | 12.60% |
| Oats (Winnipeg) | 37 | 21.62% | 21.62% |
| Wheat | 200 | 44.50% | 10.00% |
| Wheat (Kansas City) | 115 | 35.65% | 14.78% |
| Wheat (London) | 33 | 54.54% | 6.06% |
| Cocoa | 200 | 42.50% | 14.00% |
| Frozen Orange Juice | 195 | 36.41% | 12.82% |
| Coffee | 132 | 46.21% | 15.09% |
| Coffee (London) | 39 | 17.94% | 15.38% |
| Rough Rice | 77 | 42.86% | 11.68% |
| Sugar #14 | 37 | 54.05% | 10.81% |
| Cotton #2 | 198 | 52.52% | 13.63% |
| Lumber | 156 | 64.74% | 0.641% |
| Barley (London) | 27 | 37.07% | 3.70% |
| Potatoes (London) | 25 | 32.00% | 4.00% |
| Rapeseed (Winnipeg) | 103 | 42.71% | 16.50% |
| Feeder Cattle | 202 | 42.57% | 6.93% |
| Live Cattle | 184 | 62.50% | 2.17% |
| Lean Hogs | 209 | 63.16% | 4.78% |
| **Total** | **3511** | **45.66%** | **11.10%** |
| **Energy** | | | |
| Crude Oil | 199 | 52.26% | 15.57% |
| Heating Oil | 240 | 50.00% | 15.83% |
| Unleaded Gasoline | 179 | 54.19% | 11.17% |
| Natural Gasoline | 115 | 89.57% | 1.74% |
| Propane Gas | 145 | 37.24% | 21.37% |
| **Total** | **865** | **54.44%** | **12.90%** |
| **Metals** | | | |
| Gold | 173 | 27.17% | 22.54% |
| High Grade Copper | 286 | 41.26% | 4.19% |
| Palladium | 91 | 24.18% | 36.26% |
| Silver | 210 | 27.62% | 22.38% |
| **Total** | **760** | **32.24%** | **17.23%** |

Table II (continued)

| Commodity | Number of Contracts | $\beta_1 < 0$ | $\beta_1 > 0$ |
|---|---|---|---|
| **Stock Index** | | | |
| Eurotop-100 Index | 28 | 21.43% | 25.00% |
| Municipal Bonds | 58 | 8.62% | 36.32% |
| S&P 400 Mid Cap Index | 32 | 15.63% | 21.87% |
| 3-Month Can. Bankers Acc | 23 | 0.00% | 56.52% |
| Nikkei 225 Stock Index | 36 | 22.22% | 36.11% |
| Russell 2000 (day) | 28 | 17.86% | 21.42% |
| S&P 500 Index | 71 | 19.72% | 25.35% |
| NY Stock Composite Index | 67 | 8.96% | 22.38% |
| All Ordinary Index | 34 | 14.71% | 26.47% |
| Tokyo Stock Price Index | 30 | 3.33% | 26.66% |
| FTSE 100 Index | 63 | 15.87% | 30.16% |
| **Total** | **470** | **13.8%** | **28.90%** |
| **Interest Rate** | | | |
| Eurodollar | 68 | 23.80% | 36.47% |
| Libor (1 Month) | 116 | 2.59% | 58.62% |
| 30-day Interest Rate | 45 | 0.00% | 62.22% |
| Five Year Treasury Note | 47 | 10.64% | 17.02% |
| Ten Year Treasury Note | 71 | 12.68% | 11.26% |
| US Treasury Composite | 89 | 38.20% | 28.71% |
| Australian 10 Year Bond | 32 | 12.50% | 6.25% |
| Australian 3 Year Bond | 32 | 15.63% | 6.25% |
| Japanese 10 Yr Gov. Bond | 30 | 10.00% | 23.33% |
| Long Gilt (20 Year) | 38 | 10.52% | 21.12% |
| **Total** | **638** | **13.80%** | **31.10%** |
| **Currency** | | | |
| Australian Dollar | 40 | 20.00% | 12.50% |
| British Pound | 98 | 14.29% | 21.43% |
| Canadian Dollar | 91 | 18.68% | 32.97% |
| German Mark | 98 | 18.37% | 16.33% |
| Dollar Index | 20 | 20.00% | 10.00% |
| French Franc | 24 | 12.50% | 12.50% |
| Japanese Yen | 92 | 16.30% | 16.30% |
| Swiss Franc | 98 | 15.31% | 19.39% |
| **Total** | **561** | **16.75%** | **19.78%** |

Table III

The relationship between the maturity effect and covariance between spot price and net carry cost

The third and fourth columns report the percentage of contracts showing negative and positive covariance of net carry cost and spot price, respectively. The fifth column shows the percentage of contracts that have negative covariance and maturity effect out of all contracts that exhibit maturity effect. The sixth column reports the percentage of contracts that have positive covariance out of all contracts that demonstrate decreasing volatility. The last two columns report the percentage of contracts that support and contradict the maturity effect.

$$\sigma^2_{j,t} = \beta_0 + \beta_1 \tau_{j,t} + \varepsilon_t$$

$$c_{j,t} = \alpha_0 + \alpha_1 Ln(S_{j,t}) + \varepsilon_t$$

| Commodity | Number of Contracts | $\alpha_1 < 0$ | $\alpha_1 > 0$ | $\alpha_1 < 0$ $\beta_1 < 0$ | $\alpha_1 > 0$ $\beta_1 > 0$ | $\beta_1 < 0$ | $\beta_1 > 0$ |
|---|---|---|---|---|---|---|---|
| **Agricultural** | | | | | | | |
| Soybean Oil | 319 | 87.46% | 6.58% | 86.51% | 3.70% | 39.50% | 8.46% |
| Soybeans | 278 | 70.86% | 18.35% | 71.67% | 21.43% | 43.17% | 15.07% |
| Soybean Meal | 320 | 87.50% | 4.69% | 93.51% | 11.36% | 48.13% | 13.75% |
| Corn | 195 | 81.54% | 10.26% | 80.56% | 17.65% | 36.92% | 17.43% |
| Oats | 230 | 83.91% | 2.61% | 83.67% | 3.45% | 42.61% | 12.60% |
| Oats (Winnipeg) | 37 | 75.68% | 5.41% | 62.50% | 0.00% | 21.62% | 21.62% |
| Wheat | 200 | 81.00% | 9.50% | 80.90% | 15.00% | 44.50% | 10.00% |
| Wheat (Kansas City) | 115 | 75.65% | 15.65% | 82.93% | 23.53% | 35.65% | 14.78% |
| Wheat (London) | 33 | 90.91% | 3.03% | 94.44% | 0.00% | 54.54% | 6.06% |
| Cocoa | 200 | 83.50% | 7.50% | 85.88% | 3.57% | 42.50% | 14.00% |
| Frozen Orange Juice | 195 | 69.74% | 15.38% | 64.79% | 12.00% | 36.41% | 12.82% |
| Coffee | 132 | 72.73% | 15.91% | 62.30% | 0.00% | 46.21% | 15.09% |
| Coffee (London) | 39 | 51.28% | 28.21% | 9.38% | 16.67% | 17.94% | 15.38% |
| Rough Rice | 77 | 75.32% | 9.09% | 59.09% | 0.00% | 42.86% | 11.68% |
| Sugar #14 | 37 | 94.59% | 0.00% | 95.00% | 0.00% | 54.05% | 10.81% |
| Cotton #2 | 198 | 80.81% | 10.10% | 87.50% | 11.11% | 52.52% | 13.63% |
| Lumber | 156 | 91.03% | 3.85% | 62.82% | 0.00% | 64.74% | 0.641% |
| Barley (London) | 27 | 70.37% | 3.70% | 50.00% | 0.00% | 37.07% | 3.70% |
| Potatoes (London) | 25 | 68.75% | 3.13% | 87.50% | 0.00% | 32.00% | 4.00% |
| Rapeseed (Winnipeg) | 103 | 75.73% | 14.56% | 68.18% | 5.88% | 42.71% | 16.50% |
| Feeder Cattle | 202 | 75.25% | 13.86% | 69.77% | 7.14% | 42.57% | 6.93% |
| Live Cattle | 184 | 94.57% | 1.63% | 96.52% | 0.00% | 62.50% | 2.17% |
| Lean Hogs | 209 | 83.25% | 9.09% | 85.61% | 10.00% | 63.16% | 4.78% |
| **Total** | **3511** | **80.97%** | **9.39%** | **79.97%** | **11.28%** | **45.66%** | **11.10%** |
| **Currency** | | | | | | | |
| Australian Dollar | 40 | 27.50% | 12.50% | 42.86% | 0.00% | 20.00% | 12.50% |
| British Pound | 73 | 28.77% | 23.29% | 22.22% | 12.50% | 14.29% | 21.43% |
| Canadian Dollar | 90 | 27.78% | 40.00% | 23.53% | 32.26% | 18.68% | 32.97% |
| German Mark | 98 | 27.55% | 18.37% | 27.27% | 17.86% | 18.37% | 16.33% |
| Dollar Index | 20 | 65.00% | 10.00% | 100.00% | 0.00% | 20.00% | 10.00% |
| French Franc | 24 | 41.67% | 8.33% | 66.67% | 0.00% | 12.50% | 12.50% |
| Japanese Yen | 92 | 25.00% | 38.04% | 25.00% | 34.78% | 16.30% | 16.30% |
| Swiss Franc | 98 | 27.55% | 26.53% | 28.57% | 28.57% | 15.31% | 19.39% |
| **Total** | **561** | **29.3%** | **26.36%** | **35.51%** | **25.92%** | **16.75%** | **19.78%** |