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Abstract

In a seminal article, Samuelson (1965) proposes the maturity effect that volatility of futures prices should increase as futures contract approaches maturity. This study provides new evidence on the maturity effect by examining a more extensive set of futures contracts than previous studies and analyzing each contract separately. Using 6805 futures contracts drawn from 61 commodities, including some data from non-US markets, we find that the maturity effect is absent in the majority of contracts. In addition, the maturity effect tends to be stronger in agricultural and energy commodities than in financial futures. We also examine the hypothesis in Besssembinder, Coughenour, Seguin, and Smoller (1996), which states that negative covariance between the spot price and net carry cost causes the maturity effect in futures. Our results provide very weak evidence in favor of this hypothesis.

I. Introduction

In a seminar article, Samuelson (1965) hypothesizes that price variability increases as time-to-maturity approaches. This maturity effect is important in many aspects. For example, the relation between volatility and maturity is relevant for margin setting and hedging strategy. Specifically, the desired margin size is a positive function of futures price volatility. Therefore, if volatility increases near delivery, margins should also be set higher and hedging strategies should be monitored and adjusted as the delivery date approaches. Finally, because volatility is one of the factors determining the price of an option, the maturity effect should be taken into consideration with regard to the pricing of options on futures

Many studies empirically test the validity of the Samuelson hypothesis. The vast majority of these studies examine a limited set of commodities. In order to provide more general results, this study employs a more extensive set of futures contracts than previous studies. Specifically, we utilize data of 6805 futures contracts drawn from 61 commodities. The data covers a longer time period (1960 to 2000), and include both US and non-US futures exchanges (London, Sydney, Tokyo and Winnipeg Futures). To our knowledge, these markets have not been included in previous studies. The use of the more extensive and new data also addresses the potential data snooping bias.

This paper uses an alternative approach to examine the maturity effect. Specifically, each individual contract is analyzed separately, as opposed to extant literature that aggregates the contracts by using constructed time series. This alternative methodology is advantageous because it avoids the aggregation problems that can distort empirical results. [1] We also present an analysis of the role of covariance between changes in spot prices and carry costs in explaining the maturity effect. Bessembinder, Coughenour, Seguin and Smoeller (1996, henceforth BCSS) hypothesize 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 does this study.

Our primary results can be summarized as follows. First, the maturity effect is absent in the majority of futures contracts. This result is in contrast to the findings in most empirical studies. Our robustness tests suggest that the strong evidence in favor of maturity effect is primarily due to the aggregate approach applied in the existing studies. In particular, when we pool the contracts using the conventional methods, we find that almost all commodities exhibit significant maturity effect. Second, the maturity effect varies substantially across contracts and commodities. The evidence in favor of maturity effect tends to be stronger for agricultural and energy commodities than for financial assets. Third, the evidence supporting the BCSS hypothesis is quite weak. There seems to be other factors besides the negative covariance between prices and carry costs that can induce maturity effect in futures prices.

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

II. Related Literature

[1] Ma, Mercer and Walker (1992) provide a more detailed discussion on how aggregating contracts distorts the empirical results.

Samuelson (1965) hypothesizes that price volatility should increase as the delivery date of futures contract approaches. Anderson and Danthine (1983) reinterpret the maturity effect by incorporating time-varying rate of information flow. They hypothesize that the maturity effect reflects a greater rate of information flow near maturity, as more traders spend time and resource to uncover new information.

A recent theoretical analysis for the maturity effect is introduced by Bessembinder, Coughenour, Seguin and Smoeller (1996) (BCSS, thereafter), in which they develop a framework to predict markets in which the maturity effect is likely to exist. They state 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

$$\sigma_F^2 = \sigma_S^2 + \tau^2\sigma_c^2 + 2\tau Cov(c, Ln(S_t)) \text{ ..(2)}$$

where σ_F^2 is the variance of futures; σ_S^2 is the variance of spot; σ_c^2 is the variance of the net carry cost (which is reflected in the 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 both nearby and distant contracts. This would imply 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.[2] If $\sigma_c^2 > 0$ and is constant, reduction in τ^2 over time will cause futures volatility to decline as delivery approaches, which is contrary to the maturity effect. Thus this is also rejected as a potential explanation for the maturity effect by BCSS. Only the last term can have a positive or a negative effect on futures volatility. Therefore, they conclude that the maturity effect should be present when the covariance between net carry cost and the spot price is sufficiently negative to outweigh the positive effect of $\tau^2\sigma_c^2$. Intuitively, a negative covariance implies that spot price changes in the future are to some extent temporarily predictable. The presence of a predictable component must in equilibrium be offset by variations in carry costs, which are reflected in futures prices of various delivery dates. Stated differently, a temporary component in price changes implies that price reversals are likely and price volatility is high especially near maturity when spot price and futures price must converge. It should be emphasized that negative covariance is only a necessary but not sufficient condition for the hypothesis, because the second term in particular implies the volatility has a tendency to decay as maturity nears, holding other factors constant.[3]

[2] This also suggests a weakness of the rate of information flow as a potential explanation for the maturity effect. If the rate of information flow does increase near maturity, greater volatility should be evident in all contracts regardless of their maturities.

[3] This time decay effect is consistent with the convergence effect: futures price must converge to the spot price upon delivery. We thank the referee for pointing this out.

A testable hypothesis of the BCSS model is that the maturity effect will tend to hold when the covariance is negative. In their paper, BCCS also argue that the covariance is likely to be negative for real assets, 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 often lead to both increased convenience yields and spot prices. Seasonality in consumption could also induce positive correlation between yields and prices. Because convenience yield for financial assets is generally low, this hypothesis applies to a less extent to financial futures.

Overall, extant empirical evidence regarding the maturity effect is mixed, but the effect seems to be stronger for non-financial futures than for 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 observations 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 finds 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. The empirical evidence largely supports 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 only weakly consistent with the maturity effect.

Galloway and Kolb (1996) examine a comprehensive data set, including 45 commodities over the period 1969 to 1992. 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 eleven commodities over roughly a ten-year period. They find that the maturity effect tends to be present 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 does this study. Additionally, because they present one aggregate covariance estimate for each commodity, the sample size for their analysis is in effect eleven.

III. Data and Methodology

The data in this study consists of daily settlement prices for futures contracts that matured 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 6805 futures contracts on 61 commodities, covering the major international exchange markets. Table 1 provides descriptive information for each commodity, including the beginning year of futures price data, the number of contracts, and the maturity months of the futures contact.

As shown in Table 1, 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 contracts represent the largest portion of our sample due to the longer history of these 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 interest rate futures, and mid 80's for index futures.

In addition to the U.S. futures markets, our data set contains 13 commodities drawn form four exchanges outside U.S. -- London, Sydney, Tokyo and Winnipeg. This data is more comprehensive than previous studies in three manners: a much greater number of contracts, longer period of time coverage (almost full coverage from the time prospective), and the coverage of non-US 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; and τ is the number of days until maturity. The hypothesis is that if the maturity effect is present, the coefficient β_1 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 levels 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. They recommend methodologies that avoid this linking procedure. Therefore, in this study, we analyze each contract individually. Another reason for adopting this approach is that it utilizes the full extent of information provided by the data. Consequently, thousands of contracts need to be analyzed and it is not a straight-forward matter to summarize the results. We choose to focus on the percentage of contracts that is consistent with the maturity effect; this approach 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.[4] The main reason for working with the log differences is that as price level changes we expect the dispersion of prices to change in the same direction; using percentage changes or log differences adjusts for this source of non-stationarity. 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*.

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

[4] Futures prices in the maturity month are excluded in this study, due to generally low trading in maturity months and the tendency for futures price to converge to spot price near maturity. This follows the practice of most empirical studies (e.g., Galloway and Kolb (1996)).

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 for BCCS (1996) hypothesis, we follow Bessembinder, Coughenour, Seguin, and Smoeller (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 performed to estimate the covariance sign between the spot price 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 2 presents the results of the maturity effect for each commodity. The third column reports the percentage of contracts that is consistent with the maturity effect ($\beta_1 < 0$ with 95% confidence), while the fourth and fifth columns show the percentage of contracts that do not support the maturity effect ($\beta_1 > 0$ and $\beta_1 = 0$). The results across commodities and exchanges show that from the 61 commodities, only futures on live cattle, lean hogs, and natural gasoline have percentages that are significantly greater than 50%. Sector results indicate that only energy commodities have a significantly high percentage (54.4%) of individual contracts that exhibit maturity effect. Although the maturity effect is present in a relatively high percentage (45.66%) of agricultural contracts, it does not constitute a majority of the contracts in this sector.

Index and interest-rate futures in general show fairly weak maturity effects: only 13.8% of the contracts exhibit maturity effect. 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: 32%. Similar results are documented for currency futures. We also note that many financial contracts and assets have a beta that is insignificantly different from zero. Commodities traded in non-US exchanges are highlighted by parentheses that specify their trading locations. The maturity effect is weak for these exchanges; for instance, only around 36% of agricultural contracts on these exchanges exhibit the maturity effect. For some foreign exchanges, a potential factor to be considered is the lower liquidity relative to the US. Overall, the results for individual contracts across commodities and exchanges suggest that the maturity effect is weaker than documented in the literature since it is absent in the majority of contracts. This new result can be primarily attributed to the individual contract approach employed in this study.

To verify this conclusion, we follow the conventional approach in examining the maturity effect: pooling all contracts and controlling for the year and month effects, as shown in the appendix.[5] As expected, the evidence for maturity effect is noticeably stronger, with virtually all agricultural futures indicating significant maturity effects. It implies that extreme estimates in the presence of maturity effect bias the overall results. Our individual contract approach resolves this aggregation problem and provides better insights into the maturity effect.

We then investigate the BCCS (1996)'s explanation for the maturity effect. To estimate covariance between net carry costs and spot prices, data for spot prices is needed. 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 real commodities. We use agricultural contracts as representatives for non-financials, since these contracts account for the around half of the data and have the longest history. For agricultural contracts, nearby futures prices are employed as proxies for spot prices (Fama and French (1988)). These covariance estimates are displayed in Table 3. A large percentage, roughly 81%, of agricultural contracts has negative covariance between carry costs and spot prices. For currencies futures contracts, the covariance between carry costs and spot prices does not have the tendency to be negative: the percentages of negative and positive covariance are roughly the same. This is consistent with the notion that the convenience yield for financial futures is low and/or its relationship with spot prices tends to be non-positive.

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[5] 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.

Table 4 illustrates the relation between the maturity effect and the covariance of the spot price and the carry costs. Recall from equation (2) that a negative covariance is the cause for maturity effect under the BCSS hypothesis. The notation $\alpha_1 < 0/ \beta_1 < 0$ denotes the percentage of contracts with negative covariance between carry cost and spot price, conditional on the presence of the maturity effect. When this percentage is significantly high relative to $\alpha_1 < 0/ \beta_1 \geq 0$, we can infer that if there is a maturity effect, then most likely the covariance is negative. We note that this does not imply any causality relation, but rather that maturity effect goes hand in hand with negative covariance. To determine causality, we also need to examine $\beta_1 < 0/\alpha_1 < 0$ and $\beta_1 < 0/ \alpha_1 \geq 0$. Simple *t*-tests show that the difference between $\alpha_1 < 0/ \beta_1 \geq 0$ and $\alpha_1 < 0/ \beta_1 < 0$ is statistically insignificant. Note, however, that for a few commodities, in particular soybean meal, wheat traded on Kansas City and London, cotton, potatoes, Australian dollar, dollar index, and French franc, $\alpha_1 < 0/ \beta_1 < 0$ is substantially greater than $\alpha_1 < 0/\beta_1 \geq 0$. We further find that the percentages for $\beta_1 < 0/\alpha_1 < 0$ and $\beta_1 < 0/ \alpha_1 \geq 0$ are not statistically different. These results indicate that on average the sign of beta does not depend on the covariance, with the exception of a few assets.

V. Summary and Conclusions

This paper uses an alternative approach to examine the maturity effect in futures prices. Our method is based on analyzing each individual contract separately and, therefore, avoids the aggregation problem encountered in the literature. We also examine the role that covariance between spot price and net carry cost plays in explaining the maturity effect. This paper uses a large set of data that consists of 6805 contracts on 61 commodities and includes both US and non-US futures exchanges.

We find that examining each contract individually provides new insight for the maturity effect. Specifically, the maturity effect is absent in the majority of contracts. Our results also indicate that the maturity effect tends to be stronger for commodity contracts, compared to financial futures. The results indicate that the conventional aggregation method distorts the results in favor of maturity effect. In examining the causes of maturity effect, we find that the negative covariance between spot price and net carry cost does not play a significant role for the vast majority of contracts. Our empirical analysis does not exclude increasing information flow near maturity as another explanation for the maturity effect (Anderson and Danthine (1983)). An ideal study would compare the relative importance of this information flow explanation and the covariance effect. Nevertheless, a reliable measure of information flow arguably is unavailable. For instance, trading volume is almost always higher near maturity due to greater (rollover) hedging and arbitrage activities, so it is probably not a suitable measure. The issue is left for future research.

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		Year Effect	Calendar Month Effect	
			H0: $\lambda_y = 0 \ \forall y_i$	H0: $\alpha_i = 0 \ \forall i$	
	β_1	t_B	F-statistics	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 β_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
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

** significantly different from zero at the 5% level
* significantly different from zero at the 10% level

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Table 1
Descriptive Information on Sample
(Data up 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
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
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

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Table 1 (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
SI	Silver	1964	185	1,3,5,7,9,12
		Index Based Items		
ET	Eurotop-100 Index	1992	36	3,6,9,12
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
		International Markets		
		London Markets		
LBR	Barley	1994	35	1,3,5,9,11
LKC	Coffee - Metric	1993	48	1,3,5,7,9,11
LFX	FTSE 100 Index	1984	68	3,6,9,12
LFG	Long Gilt (20 Year)	1990	44	3,6,9,12
LPO	Potatoes	1994	35	3,4,5,6,11
LW	Wheat	1994	42	1,3,5,7,9,11
		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
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

Table 2
Contracts consistent with the Maturity Effect

Results from the following regression where the dependent variable is daily volatility and the independent variable is time to maturity:

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

Commodity	Number of Contracts	$\beta_1 < 0$	$\beta_1 > 0$	$\beta_1 = 0$
Agricultural				
Soybean Oil	319	126 (39.5%)	27 (8.5%)	166 (52.0%)
Soybeans	278	120 (43.2%)	42 (15.1%)	116 (41.8%)
Soybean Meal	320	154 (48.1%)	44 (13.8%)	122 (38.1%)
Corn	195	72 (36.9%)	34 (17.4%)	89 (45.7%)
Oats	230	98 (42.6%)	29 (12.6%)	103 (44.8%)
Oats (Winnipeg)	37	8 (21.6%)	8(21.6%)	21 (56.8%)
Wheat	200	89 (44.5%)	20 (10.0%)	91 (45.5%)
Wheat-Kansas City	115	41(35.7%)	17 (14.8%)	57 (49.6%)
Wheat (London)	33	18 (54.5%)	2 (6.1%)	13 (39.4%)
Cocoa	200	85 (42.50%)	28 (14.00%)	87 (43.5%)
Frozen Orange Juice	195	71 (36.4%)	25 (12.8%)	99 (50.8%)
Coffee	132	61 (46.2%)	20 (15.1%)	51 (38.7%)
Coffee (London)	39	7 (17.9%)	6 (15.4%)	26 (66.7%)**
Rough Rice	77	33 (42.9%)	9 (11.7%)	35 (45.5%)
Sugar #14	37	20 (54.1%)	4 (10.8%)	13 (35.1%)
Cotton #2	198	104 (52.5%)	27 (13.6%)	67 (33.9%)
Lumber	156	85 (54.5%)	1 (0.6%)	70 (44.9%)
Barley (London)	27	10 (37.1%)	1 (3.7%)	16 (59.2%)
Potatoes (London)	25	8 (32.0%)	1 (4.0%)	16 (64.0%)**
Rapeseed (Winnipeg)	103	44 (42.7%)	17 (16.5%)	42 (40.8%)
Feeder Cattle	202	86 (42.6%)	14 (6.9%)	102 (50.5%)
Live Cattle	184	115 (62.5%)**	4 (2.2%)	65 (35.3%)
Lean Hogs	209	132 (63.2%)**	10 (4.8%)	67 (32.1%)
Total	**3511**	**1603 (45.7%)**	**390 (11.1%)**	**1518 (43.2%)**
Energy				
Crude Oil	199	104 (52.3%)	31 (15.6%)	64 (32.2%)
Heating Oil	240	120 (50.0%)	38 (15.8%)	82 (34.2%)
Unleaded Gasoline	179	97 (54.2%)	20 (11.2%)	62 (34.6%)
Natural Gasoline	115	103 (89.6%)**	2 (1.7%)	10 (8.7%)
Propane Gas	145	54 (37.2%)	31 (21.4%)	60 (41.4%)
Total	**878**	**478 (54.4%)****	**122 (13.9%)**	**278 (31.7%)**
Metals				
Gold	173	47 (27.2%)	39 (22.5%)	87 (50.3%)
High Grade Copper	286	118 (41.3%)	12 (4.2%)	156 (54.6%)*
Palladium	91	22 (24.2%)	33 (36.3%)	36 (39.6%)
Silver	210	58 (27.6%)	47 (22.4%)	105 (50.0%)
Total	**760**	**245 (32.2%)**	**131 (17.2%)**	**384 (50.5%)**

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Table 2 (continued)

Commodity		Number of Contracts	$\beta_1 < 0$	$\beta_1 > 0$	$\beta_1 = 0$
Stock Index					
Eurotop-100 Index		28	6 (21.4%)	7 (25.0%)	15 (53.6%)
Municipal Bonds		58	5 (8.6%)	21 (36.3%)	32 (55.1%)
S&P 400 Mid Cap Index		32	5 (15.6%)	7 (21.9%)	20 (62.5%)*
3-Month Can. Bankers Acc		23	0 (0.0%)	13 (56.5%)	10 (43.5%)
Nikkei 225 Stock Index		36	8 (22.2%)	13 (36.1%)	15 (41.7%)
Russell 2000 (day)		28	5 (17.9%)	6 (21.4%)	17 (60.7%)*
S&P 500 Index		71	14 (19.7%)	18 (25.4%)	39 (54.9%)
NY Stock Composite Index		67	6 (9.0%)	15 (22.4%)	46 (68.7%)**
All Ordinary Index	(Sydney)	34	5 (14.7%)	9 (26.5%)	20 (58.8%)
Tokyo Stock Price Index	(Tokyo)	30	1 (3.3%)	8 (26.7%)	21 (70.0%)**
FTSE 100 Index	(London)	63	10 (15.9%)	19 (30.2%)	34 (54.0%)
Total		**470**	**65 (13.8%)**	**136 (28.9%)**	**269 (57.2%)****
Interest Rate					
Eurodollar		68	16 (23.8%)	25 (36.5%)	27 (57.2%)
Libor (1 Month)		116	3 (2.6%)	68 (58.6%)**	45 (38.8%)
30-day Interest Rate		45	0 (0.0%)	28 (62.2%)**	17 (37.8%)
Five Year Treasury Note		47	5 (10.6%)	8 (17.0%)	34 (72.3%)**
Ten Year Treasury Note		71	9 (12.7%)	8 (11.3%)	54 (76.1%)**
US Treasury Composite		89	34 (38.2%)	26 (28.7%)	29 (33.1%)
Australian 10 Year Bond	(Sydney)	32	4 (12.5%)	2 (6.3%)	26 (81.3%)**
Australian 3 Year Bond	(Sydney)	32	5 (15.6%)	2 (6.3%)	25 (78.1%)**
Japanese 10 Yr Gov. Bond	(Tokyo)	30	3 (10.0%)	7 (23.3%)	20 (66.7%)**
Long Gilt (20 Year)	(London)	38	4 (10.5%)	8 (21.1%)	26 (68.4%)**
Total		**568**	**83 (13.8%)**	**182 (32.0%)**	**303 (53.4%)***
Currency					
Australian Dollar		40	8 (20.0%)	5 (12.5%)	27 (67.5%)**
British Pound		98	14 (14.3%)	21 (21.4%)	63 (64.3%)**
Canadian Dollar		91	17 (18.7%)	30 (33.0%)	44 (48.4%)
German Mark		98	18 (18.4%)	16 (16.3%)	64 (65.3%)**
Dollar Index		20	4 (20.0%)	2 (10.0%)	14 (70.0%)**
French Franc		24	3 (12.5%)	3 (12.5%)	18 (75.0%)**
Japanese Yen		92	15 (16.3%)	15 (16.3%)	62 (67.4%)**
Swiss Franc		98	15 (15.3%)	19 (19.4%)	64 (65.3%)**
Total		**561**	**94 (16.8%)**	**111 (19.8%)**	**356 (63.5%)****

** significantly greater than 50% at the 5% level

* significantly greater than 50% at the 10% level

Table 3
Covariance between spot price and net carry cost

Results from the following regression where the dependent variable is carry cost and the independent variable is log of spot price:

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

Commodity	Number of Contracts	$\alpha_1 < 0$	$\alpha_1 > 0$	$\alpha_1 = 0$
Agricultural				
Soybean Oil	319	279 (87.5%)**	21 (6.6%)	19 (6.0%)
Soybeans	278	197 (70.9%)**	51 (18.4%)	30 (10.8%)
Soybean Meal	320	280 (87.5%)**	15 (4.7%)	25 (7.8%)
Corn	195	159 (81.5%)**	20 (10.3%)	16 (8.2%)
Oats	230	193 (83.9%)**	6 (2.6%)	31 (13.5%)
Oats (Winnipeg)	37	28 (75.7%)**	2 (5.4%)	7 (18.9%)
Wheat	200	162 (81.0%)**	19 (9.5%)	19 (9.5%)
Wheat -Kansas City	115	87 (75.7%)**	18 (15.7%)	10 (8.7%)
Wheat (London)	33	30 (90.9%)**	1 (3.0%)	2 (6.1%)
Cocoa	200	167 (83.5%)**	15 (7.5%)	18 (9.0%)
Frozen Orange Juice	195	136 (69.7%)**	30 (15.4%)	29 (14.9%)
Coffee	132	96 (72.7%)**	21 (15.9%)	15 (11.4%)
Coffee (London)	39	20 (51.3%)	11 (28.2%)	8 (20.5%)
Rough Rice	77	58 (75.3%)**	7 (9.1%)	12 (15.6%)
Sugar #14	37	35 (94.6%)**	0 (0.0%)	2 (5.4%)
Cotton #2	198	160 (80.8%)**	20 (10.1%)	18 (9.1%)
Lumber	156	142 (91.0%)**	6 (3.9%)	8 (5.1%)
Barley (London)	27	19 (70.4%)**	1 (3.7%)	7 (25.9%)
Potatoes (London)	25	17 (68.8%)**	1 (3.1%)	7 (28.1%)
Rapeseed (Winnipeg)	103	78 (75.7%)**	15 (14.6%)	10 (9.7%)
Feeder Cattle	202	152 (75.3%)**	28 (13.9%)	22 (10.9%)
Live Cattle	184	174 (94.6%)**	3 (1.6%)	7 (3.8%)
Lean Hogs	209	174 (83.3%)**	19 (9.1%)	16 (7.7%)
Total	**3511**	**2843 (81.0%)****	**330 (9.4%)**	**338 (9.6%)**
Currency				
Australian Dollar	40	11 (27.5%)	5 (12.5%)	24 (60.0%)*
British Pound	73	21 (28.8%)	17 (23.3%)	35 (48.0%)
Canadian Dollar	90	25 (27.8%)	36 (40.0%)	29 (32.2%)
German Mark	98	27 (27.6%)	18 (18.4%)	53 (54.1%)
Dollar Index	20	13 (65.0%)**	2 (10.0%)	5 (25.0%)
French Franc	24	10 (41.7%)	2 (8.3%)	12 (50.0%)
Japanese Yen	92	23 (25.0%)	35 (38.0%)	34 (37.0%)
Swiss Franc	98	27 (27.6%)	26 (26.5%)	45 (45.9%)
Total	**561**	**164 (29.3%)**	**148 (26.4%)**	**249 (44.4%)**

** significantly greater than 50% at the 5% level
* significantly greater than 50% at the 10% level

Table 4
The relationship between the maturity effect and covariance of spot price and net carry cost

Estimates for β_1 (coefficient of volatility on time-to-maturity, $\beta_1 < 0$ presents a maturity effect) and α_1 (covariance between spot price and net carry cost) are obtained from the following regressions:

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

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

Commodity	$\alpha_1 < 0/ \beta_1 < 0$	$\alpha_1 < 0/ \beta_1 \geq 0$	difference	$\beta_1 < 0/ \alpha_1 < 0$	$\beta_1 < 0/ \alpha_1 \geq 0$	difference
Agricultural						
Soybean Oil	86.5%	88.1%	-1.6%	39.1%	42.5%	-3.4%
Soybeans	71.7%	70.3%	1.4%	43.7%	42.0%	1.7%
Soybean Meal	93.5%	81.9%	11.6%	51.4%	25.0%	26.4%
Corn	80.6%	82.1%	-1.6%	36.5%	38.9%	-2.4%
Oats	83.7%	84.1%	-0.4%	42.5%	43.2%	-0.7%
Oats (Winnipeg)	62.5%	79.3%	-16.8%	17.9%	33.3%	-15.5%
Wheat	80.9%	81.1%	-0.2%	44.4%	44.7%	-0.3%
Wheat -Kansas City	82.9%	71.6%	11.3%	39.1%	25.0%	14.1%
Wheat (London)	94.4%	86.7%	7.8%	56.7%	33.3%	23.4%
Cocoa	85.9%	81.7%	4.1%	43.7%	36.4%	7.4%
Frozen Orange Juice	64.8%	72.6%	-7.8%	33.8%	42.4%	-8.6%
Coffee	62.3%	81.7%	-19.4%	39.6%	63.9%	-24.3%
Coffee (London)	14.3%	59.4%	-45.1%	5.0%	31.6%	-26.6%
Rough Rice	60.6%	86.4%	-25.8%	34.5%	68.4%	-33.9%
Sugar #14	95.0%	94.1%	0.9%	54.3%	50.0%	4.3%
Cotton #2	87.5%	73.4%	14.1%	56.9%	34.2%	22.7%
Lumber	94.1%	87.3%	6.8%	56.3%	35.7%	20.6%
Barley (London)	50.0%	82.4%	-32.4%	26.3%	62.5%	-36.2%
Potatoes (London)	87.5%	58.8%	28.7%	41.2%	12.5%	28.7%
Rapeseed (Winnipeg)	68.2%	81.4%	-13.2%	38.5%	56.0%	-17.5%
Feeder Cattle	70.0%	79.3%	-9.5%	39.5%	52.0%	-12.5%
Live Cattle	96.5%	91.3%	5.2%	63.8%	40.0%	23.8%
Lean Hogs	85.6%	79.2%	6.4%	65.0%	54.3%	10.7%
Average	**76.5%**	**79.8%**	**-3.3%**	**42.2%**	**42.1%**	**0.1%**
Currency						
Australian Dollar	37.5%	25.0%	12.5%	27.3%	17.2%	10.1%
British Pound	20.0%	30.2%	-10.2%	9.5%	15.4%	-5.9%
Canadian Dollar	23.5%	28.4%	-4.9%	16.0%	20.0%	-4.0%
German Mark	27.8%	27.5%	0.3%	18.5%	18.3%	0.2%
Dollar Index	100%	56.3%	43.7%	30.8%	0.0%	30.8%
French Franc	66.7%	38.1%	28.6%	20.0%	7.1%	12.9%
Japanese Yen	26.7%	24.7%	2.0%	17.4%	15.9%	1.5%
Swiss Franc	26.7%	27.7%	-1.0%	14.8%	15.5%	-0.7%
Average	**41.1%**	**32.2%**	**8.9%**	**19.3%**	**13.7%**	**5.6%**