Futures Prices and the Maturity Effect

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INTRODUCTION

The issue of volatility in futures prices has been investigated extensively in the finance literature. In his seminal article, Samuelson (1965) provides a model that postulates the volatility of futures prices should increase as the contract approaches expiration. This effect, which has become known as the maturity effect, occurs because the model assumes market competition forces the spot and futures prices to converge at maturity. Thus, prices of futures contracts close to expiration react more strongly to new information about the commodity than do prices of more distant contracts, at a time when little is known about the future spot price for the underlying commodity.

Milonas (1986) studied eleven commodities and found strong support for the maturity effect after controlling for the year effect, the calendar-month (seasonality) effect, and the contract-month effect. Anderson (1985) studied nine commodities and found support for the maturity effect, but concluded it is secondary to the effect of seasonality.

This study sheds new light on the maturity effect by examining a more extensive set of futures contracts for more commodities over a longer period than previous studies. Using data on 4111 futures contracts drawn from 45 commodities over the years from 1969 to 1992, and employing an alternative methodology to control for the effects of year, calendar month, and contract month, strong support is found for the maturity effect in agricultural and energy commodities, but not in precious

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metals and financial commodities. Thus, it appears the maturity effect plays a significant role in the volatility of futures prices for those commodities that experience seasonal demand or supply, but not those for which the cost-of-carry model of futures prices works well.

The article is organized as follows. The next section presents a brief review of the related literature, emphasizing the various sources of volatility that have been identified and the theoretical models that have been proposed to explain the maturity effect. Then, the data and methodology are discussed, and the results of the empirical analysis follow. The final section presents concluding remarks.

RELATED LITERATURE

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, that affect supply or demand in the product markets. The calendar-month effect refers to the 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 expectations about crop supply. In contrast, for energy commodities, production is not very seasonal, but demand exhibits strong seasonality. For example, fuel oil has high demand in winter, while gasoline exhibits high demand in summer. The contract-month effect captures random shocks occurring because futures contracts mature in different calendar months. For example, for agricultural commodities, higher price volatility is expected for those contracts maturing shortly before harvest.

In a study of corn, wheat, and the soybean complex (soybeans, soybean meal, soybean oil) futures over the period 1966–1982, Milonas and Vora (1985) found evidence of all three sources of nonstationarity in the five commodities, but the results were weakest for soybean meal and soybean oil. Similarly, Kenyon et al. (1987) found evidence of year and calendar-month effects for corn, wheat, and soybeans. Khoury and Yourougou (1993) studied six Canadian grain and oilseed commodities (barley, oats, flaxseed, rye, wheat, canola) from 1980–1988 and found mixed support for the effects of year, calendar month, and contract month on futures price volatility.

The maturity effect, another source of nonstationarity, refers to increasing volatility of futures prices as the contract approaches expiration.

This effect was modeled by Samuelson (1965), who assumed competitive forces in the futures market ensure that the spot price and the futures price converge at maturity. The intuition behind Samuelson's model is that high price volatility implies large price changes. Price changes are larger when more information is being revealed about a commodity. Early in a contract's life, little information is known about the future spot price for the underlying commodity. Later, as the contract nears maturity, the rate of information acquisition increases, and, thus, the price volatility increases.

Early empirical evidence regarding the maturity effect hypothesis is mixed. Rutledge (1976) rejected the hypothesis for wheat and soybean oil, but accepted it for silver and cocoa. Grauer (1977) found no support for ten different commodities. More recent empirical evidence is more supportive. Dusak-Miller (1979) reported support for the maturity hypothesis for live cattle futures. Castelino and Francis (1982) found strong evidence of a maturity effect for wheat and the soybean complex during 1960–1971, while Milonas (1986) found support for the hypothesis in 10 of 11 agricultural, financial, and metals commodities from 1972–1983. Barnhill, Jordan, and Seale (1987) found evidence of a maturity effect in the Treasury-bond futures market during the period 1977–1984, and Khoury and Yourougou (1993) found support for a maturity effect in their analysis of six Canadian agricultural commodities.

Anderson and Danthine (1983) proposed a model that is more general than Samuelson's. The model allows for the simultaneous determination of equilibrium cash and futures prices in a multiperiod setting, and implies the variability of futures prices is higher in those periods when relatively large amounts of supply and demand uncertainty are resolved. Within this state-variable framework, the Samuelson hypothesis becomes a special case in which uncertainty resolution increases as the contract nears expiration.

The study of agricultural commodities allows the state-variable hypothesis to be distinguished from the maturity effect hypothesis because the resolution of uncertainty is expected to follow a strongly seasonal pattern. Anderson (1985) studied nine commodities from 1966–1980 and provided support for the maturity effect, but found the seasonal effect is a more important determinant of futures price volatility. Kenyon et al. (1987) reached a similar conclusion in their study of corn, soybeans, and wheat futures.

Given the limited number of commodities analyzed and the mixed results of prior studies, this article casts new light on the maturity effect by examining a more extensive set of commodities, including grains, other agriculturals, livestock, energy, metals, stock indexes, interest rates, and foreign currencies. Further, the futures contracts for this extensive set of commodities cover a longer period than previous studies, and an alternative methodology is used to control for the various sources of nonstationarity discussed above.

DATA AND METHODOLOGY

The data analyzed in this study consist of daily settlement prices for futures contracts that expired during the years from 1969 through 1992. The data are from Tick Data, Inc., a commercial vendor of futures data. Over 500,000 daily prices are available for 4111 futures contracts on 45 commodities. Table I provides descriptive information for each commodity, including the beginning year of futures price availability, the number of contracts analyzed, and the possible expiration months for the futures contracts.

Due to the tremendous growth of the futures markets in recent years, the daily settlement prices analyzed necessarily include more observations from the recent past. For example, wheat and soybean futures have been traded on the Chicago Board of Trade (CBOT) since 1969, but futures on the S&P 500 index began trading in 1982. Trading in liquid propane futures began in 1987. Further, because agricultural commodities are so numerous and began trading fairly early in the analysis period, they account for the largest portion of the contracts studied.[1] As shown in Table I, agricultural commodities represent 2506 contracts or 61% of the sample, while energy and metals commodities represent 11% each, and financial commodities form the remaining 17% of the sample. Finally, Table I indicates the commodities analyzed have a wide variety of possible contract months. For example, corn futures contracts can expire in the 5 months of March, May, July, September, and December. In contrast, crude oil futures contracts can mature in all 12 months of the year.

For each futures contract for each commodity, daily settlement prices are used to calculate daily futures returns and monthly variances of these returns for each of the six months preceding the expiration month of the contract. Analysis is limited to the six months preceding expiration because, for most commodities, open interest is low and trading volume is thin in periods long before maturity. In some cases, settlement prices may be "stale" even when they represent actual trade prices; and, in other cases, a settlement committee, rather than market forces, determines set-

[1]Barley, flaxseed, rapeseed, and rye are Canadian (Winnipeg) commodities. Winnipeg conducts the only barley and rye futures markets in the world, and the only flaxseed futures market in North America.

TABLE I

Descriptive Information on Sample

Commodity Type	*Beginning Year of Price Data*	*Number of Contracts*	*Possible Contract Months*
Grains and oilseeds			
Wheat—Chicago	1969	121	3,5,7,9,12
Wheat—Kansas City	1976	84	3,5,7,9,12
Wheat—Winnipeg	1980	65	3,5,7,10,11,12
Wheat-Minneapolis	1981	62	3,5,7,9,12
Soybean	1969	169	1,3,5,7,8,9,11
Soybean oil	1969	194	1,3,5,7,8,9,10,11,12
Soybean meal	1969	194	1,3,5,7,8,9,10,11,12
Corn	1969	121	3,5,7,9,12
Oats	1974	92	11
Barley	1980	65	1,3,6,9,11
Flaxseed	1981	60	3,5,7,10,11,12
Rapeseed	1980	61	1,3,6,9,11
Rye	1980	60	3,5,7,10,12
Rough rice	1986	36	1,3,5,7,9,11
Total		1384	
Other agricultural			
Cocoa	1980	61	3,5,7,9,12
Coffee	1974	99	3,5,7,9,11,12
Sugar	1973	112	1,3,5,7,9,10
Orange juice	1973	121	1,3,5,7,9,11
Cotton	1972	102	3,5,7,10,12
Lumber	1973	115	1,3,5,7,9,11
Total		610	
Livestock			
Feeder cattle	1977	127	1,3,4,5,8,9,10,11
Live cattle	1976	107	1,2,3,4,5,6,8,9,10,11,12
Live hog	1970	162	2,4,6,7,8,10,12
Pork bellies	1970	116	2,3,5,7,8
Total		512	
Energy			
Crude oil	1983	116	1,2,3,4,5,6,7,8,9,10,11,12
Heating oil	1979	158	1,2,3,4,5,6,7,8,9,10,11,12
Unleaded gas	1985	96	1,2,3,4,5,6,7,8,9,10,11,12
Liquid propane	1987	62	1,2,3,4,5,6,7,8,9,10,11,12
Total		432	
Metals			
Gold	1975	112	1,2,3,4,6,8,10,12
Silver	1973	122	1,3,5,7,9,12
Palladium	1983	42	3,6,9,12
Platinum	1973	82	1,4,7,10
Copper	1972	107	1,3,5,7,9,10,12
Total		465	

TABLE I (Continued)

Descriptive Information on Sample

Commodity Type	*Beginning Year of Price Data*	*Number of Contracts*	*Possible Contract Months*
Stock index			
S&P 500	1982	44	3,6,9,12
Major market	1985	79	1,2,3,4,5,6,7,8,9,10,11,12
NYSE Composite	1982	44	3,6,9,12
Total		167	
Interest rate			
Eurodollar	1982	44	3,6,9,12
T-bill	1976	69	3,6,9,12
T-bond	1978	62	3,6,9,12
Total		175	
Currency			
Australian dollar	1987	25	3,6,9,12
British pound	1975	71	3,6,9,12
Canadian dollar	1977	64	3,6,9,12
Deutschemark	1975	71	3,6,9,12
Japanese yen	1977	64	3,6,9,12
Swiss franc	1975	71	3,6,9,12
Total		366	

tlement prices. As for the expiration month itself, trading volume typically decreases as expiration nears because traders close their positions to avoid making or taking delivery of the commodity. Again, in such thin markets, settlement prices may not represent actual market prices. To avoid the problem of thin markets and potentially unrepresentative prices, analysis of the variance of futures returns is limited to the six months preceding the expiration month, yielding approximately 120 to 123 days of settlement price data per futures contract.

Calculating the return for a futures position is problematic because a futures position requires no investment. Following most prior studies, the return for futures contract j on day t in the kth month before expiration, $F_{j,k,t}$, is calculated as the proportional change in the settlement price from day $t-1$ to day t:

$$F_{j,k,t} = \left(\frac{S_{j,k,t}}{S_{j,k,t-1}}\right) - 1 \tag{1}$$

where $S_{j,k,t}$ is the settlement price for futures contract j on day t in month k ($k = 1$ to 6). The volatility of the daily returns for contract, j, in month k, $\sigma^2_{j,k}$, is calculated using the statistical estimator of variance:

$$\sigma_{j,k}^2 = \sum_{t=1}^{n_{j,k}} \frac{(F_{j,k,t} - \bar{F}_{j,k})^2}{n_{j,k}} \tag{2}$$

where $n_{j,k}$ is the number of observations for contract j in month k and $\bar{F}_{j,k}$ is the arithmetic average of the daily futures returns for contract j in month k.

To examine the maturity effect in a univariate setting, the monthly variances are used to determine the percentage of contracts for which the futures price volatility in a given month before expiration is larger than the volatility in the prior month. This pattern is expected if a maturity effect exists. Ratios of the monthly variances are formed also and F-tests are performed to find the percentage of contracts with significantly larger variances nearer maturity as well as further from maturity.

In a multivariate setting, the maturity effect is investigated by performing the following ordinary least squares (OLS) regression for all contracts available for each of the 45 commodities:

$$\sigma_{j,k}^2 = \alpha + \beta k + \gamma \sigma_{j,6\text{-month}}^2 + \varepsilon \tag{3}$$

where $\sigma_{j,k}^2$ is the volatility of the returns for futures contract j in the kth month before expiration of the contract; k is the time (in months) remaining for contract j to mature; and $\sigma_{j,6\text{-month}}^2$ is the variance of futures returns for contract j over the entire six-month period. This last variable is included in the model as a control variable because, in general, a given month's returns volatility is expected to be higher if the overall volatility of returns in the six months before maturity is higher, i.e., the expected sign on γ is positive. Thus, the overall volatility variable controls for the year effect, i.e., general conditions prevailing over an extended period before maturity.[2] If a maturity effect exists for futures returns volatility, the expected sign on β is negative. For each commodity, conventional t-statistics test the null hypothesis of no maturity effect, ($\beta = 0$), as well as the null hypothesis of no year effect, ($\gamma = 0$).

Milonas (1986) controlled for the year effect, as well as the calendar-month and contract-month effect, by normalizing each monthly variance of logarithmic price changes for a given contract and commodity by the geometric average of the monthly variances across all contracts open for

[2]In referring to a year effect, it is not presumed that there is something special about the volatility in a particular calendar year. Rather, in referring to the year effect, the differences in volatility that may characterize extended periods over the life of a contract are noted. Although Milonas (1986) referred to the "year effect," his normalizing procedure made it clear he was not referring to a particular calendar year as having a special influence on volatility.

trading for the given commodity.[3] In this study, the contract-month and calendar-month effects are controlled for explicitly by extending the OLS regression in eq. (3) as follows:

$$\sigma_{j,k}^2 = \beta k + \gamma\sigma_{j,6\text{-month}}^2 + \sum_i \delta_i C_{j,k,i} + \sum_{m=1}^{11} \theta_m M_{j,k,m} + \varepsilon \tag{4}$$

where $\sigma_{j,k}^2$, k, and $\sigma_{j,6\text{-month}}^2$ are as defined previously; $C_{j,k,i}$ are dummy variables for the contract month; and $M_{j,k,m}$ are dummy variables for the calendar month. The intercept is omitted because a dummy variable is included for each of the possible contract months for a given commodity. For example, as shown in Table I, a Chicago wheat futures contract can mature in March, May, July, September, and December; thus, five dummy variables, (i = 3, 5, 7, 9, 12), control for the contract-month effect. Eleven dummy variables represent the 12 possible calendar months. Once again, a conventional t-statistic tests the null hypothesis of no maturity effect, ($\beta = 0$), and the null hypothesis of no year effect, ($\gamma = 0$). Placing linear restrictions on the model in eq. (4) creates joint and individual tests of the contract-month effect and the calendar-month effect. For example, to test for contract-month and calendar-month effects jointly, (H_0: $\delta_i = 0$, $\theta_m = 0 \ \forall\ i,m$), an F-statistic is created from the error sum of squares of the full model in eq. (4) and the restricted model in eq. (3) as follows:

$$F = \frac{(SSE(R) - SSE(F))/r}{SSE(F)/(n - v)} \tag{5}$$

where SSE(R) is the error sum of squares for the restricted model; SSE(F) is the error sum of squares for the full model; r is the number of restrictions in the null hypothesis; n is the number of observations; and v is the number of independent variables in the full model.

EMPIRICAL RESULTS

Tables II and III present the results of the univariate analysis of the maturity effect. For each commodity category, Table II reports the percent-

[3]This study focuses on the last six months of trading before the delivery month for all commodities. This approach contrasts with Milonas' procedure, in which he used as many as 35 months of price data for a single contract. Because Milonas normalized variances using a geometric averaging procedure, his technique necessarily involved using considerable data from the back months, in which trading is limited and prices are, perhaps, unrepresentative. Because this study includes data for only the six months preceding expiration, Milonas' approach to normalize variances cannot be used. As the results summarized later in this article indicate, the two different methodologies reach conclusions that are basically in agreement.

TABLE II

Comparison of Monthly Variances

Commodity Type	*Number of Contracts*	*Percentage of Contracts Following Maturity Effect Rule* $\sigma_5^2 > \sigma_6^2$	$\sigma_4^2 > \sigma_5^2$	$\sigma_3^2 > \sigma_4^2$	$\sigma_2^2 > \sigma_3^2$	$\sigma_1^2 > \sigma_2^2$	$\sigma_{1-3}^2 > \sigma_{4-6}^2$
Grains and oilseeds	1384	51.2	51.6	48.6	54.5	51.1	54.7
Other agricultural	610	49.3	53.0	53.1	49.7	53.0	63.3
Livestock	512	50.0	54.5	53.1	52.5	45.9	61.7
Energy	432	51.6	53.2	51.9	54.6	56.7	56.5
Metals	465	45.2	48.0	48.2	48.8	49.3	48.6
Stock index	167	40.7	24.6	49.1	64.1	40.7	62.3
Interest rate	175	45.7	54.3	52.6	41.7	41.1	39.4
Currency	366	56.6	42.1	44.8	55.7	40.2	51.4
Total	4111	50.0	50.1	50.0	52.9	49.3	55.7

age of contracts for which the futures returns variance in a given month before expiration is larger than the variance in the previous month, as would be expected if a maturity effect exists. For example, for grains and oilseeds, 51% of the 1384 contracts analyzed have a variance in the fifth month before maturity greater than the variance in the sixth month before maturity. For energy commodities, 57% of the 432 contracts have a variance in the first month before expiration greater than the second month before expiration. A similar comparison is made for the returns variance in two subperiods: months one to three before expiration versus months four to six before expiration. For example, only 39% of the 175 interest rate contracts have a returns variance in the three months immediately before maturity that is greater than the variance in the previous three months. The last row of Table II indicates anywhere from 49% to 56% of the contracts across all commodity types behave as expected under the maturity effect hypothesis. Thus, the maturity effect appears to be a modest feature of the market; however, the effect may be more important for some commodities than for others, especially for other agricultural, livestock, and stock index futures, as illustrated by the last column of Table II. Further, the true importance of the maturity effect may be more fully revealed after controlling for the effects of year, calendar month, and contract month, as discussed below.

Although the analysis in Table II may indicate one monthly variance is greater than another, the difference between the two variances may be statistically insignificant. To address this issue, Table III reports the percentage of contracts in each commodity category with variance ratios significantly greater than one ($\alpha = .05$) based on a conventional F-test.

TABLE III

F-Tests for Variances Ratios

Panel A: Larger Variances Nearer to Maturity

Commodity Type	Number of Contracts	Percentage of Contracts with Significant (a = .05) F-Ratios: $\sigma_5^2/\sigma_6^2 > 1$	$\sigma_4^2/\sigma_5^2 > 1$	$\sigma_3^2/\sigma_4^2 > 1$	$\sigma_2^2/\sigma_3^2 > 1$	$\sigma_1^2/\sigma_2^2 > 1$	$\sigma_{1-3}^2/\sigma_{4-6}^2 > 1$
Grains and oilseeds	1384	17.2	16.0	16.1	18.6	16.0	33.4
Other agricultural	610	14.4	13.8	16.1	13.3	17.4	33.4
Livestock	512	13.7	13.9	13.7	12.7	8.2	30.9
Energy	432	10.7	9.5	10.2	8.6	12.0	22.2
Metals	465	14.0	12.7	13.1	14.4	13.1	21.3
Stock index	167	15.0	7.2	3.6	15.6	6.0	7.2
Interest rate	175	12.6	9.7	12.0	10.9	4.6	18.9
Currency	366	21.3	12.0	14.8	21.0	11.5	24.3
Total	4111	15.4	13.4	14.0	15.3	13.2	28.1

Panel B: Larger Variances Further from Maturity

Commodity Type	Number of Contracts	Percentage of Contracts with Significant (a = .05) F-Ratios: $\sigma_6^2/\sigma_5^2 > 1$	$\sigma_5^2/\sigma_4^2 > 1$	$\sigma_4^2/\sigma_3^2 > 1$	$\sigma_3^2/\sigma_2^2 > 1$	$\sigma_2^2/\sigma_1^2 > 1$	$\sigma_{4-6}^2/\sigma_{1-3}^2 > 1$
Grains and oilseeds	1384	12.8	13.4	14.0	10.1	13.5	22.2
Other agricultural	610	13.3	7.4	11.6	7.5	12.1	12.0
Livestock	512	9.8	8.4	5.9	7.0	9.4	11.3
Energy	432	10.0	9.3	8.6	8.1	8.6	13.2
Metals	465	15.1	12.9	14.0	12.3	14.8	23.4
Stock index	167	4.2	14.9	8.3	3.6	14.9	12.5
Interest rate	175	13.7	15.4	9.7	15.4	20.0	33.1
Currency	366	11.8	17.8	16.1	9.8	16.9	26.0
Total	4111	12.0	11.9	11.9	9.3	13.1	18.9

Panel A examines those contracts with significantly larger variances nearer to maturity, as expected under the maturity effect hypothesis. For example, for grains and oilseeds, 17% of the contracts have a variance ratio significantly greater than one when comparing month five to month six before maturity. For livestock and interest rate commodities, 31% and 19%, respectively, of the variance ratios are significantly greater than one when comparing the three months immediately before maturity to the previous three months. Across all commodities for this same time comparison, 28% of the contracts behave as expected if a maturity effect exists.

Panel B of Table III examines those contracts whose variance ratios indicate higher volatility further from maturity, a pattern directly opposite to that predicted by the maturity effect. For example, for livestock commodities, while Panel A indicates 31% of the contracts behave in accordance with a maturity effect, Panel B indicates 11% of the contracts have variance ratios significantly greater than one when comparing the three months furthest from maturity to the three months closest to maturity. Across all commodities, 19% of the variance ratios exhibit this behavior in direct contrast to a maturity effect. Thus, just as in Table II, there appears to be only some tendency for variances to be larger closer to expiration and for this pattern to be stronger for some commodities than for others.

Because the univariate evidence indicates the maturity effect is merely a modest feature of the market, the maturity effect hypothesis is examined in a multivariate setting to control for influences such as the year effect, i.e., general conditions in areas such as the weather and politics prevailing for an extended time before maturity. Table IV presents the results of the OLS regression in eq. (3) for each of the 45 commodities. The table reports the coefficient estimates and the associated t-statistics, as well as the number of observations and the adjusted R^2 for each regression.[4]

In Table IV, the t-statistics for the test of the null hypothesis of no year effect, ($\gamma = 0$), indicate the null hypothesis is rejected for all 45 commodities. Further, all the estimates of γ are positive as expected, that is, the monthly variance of futures returns increases as the variance in the six months before expiration increases, holding all else constant. This result supports a year effect in which general conditions can affect supply or demand over an extended period, and agrees with Milonas and Vora (1985), who found a year effect for five agricultural commodities. Khoury and Yourougou (1993) investigated six Canadian grains and reported a year effect for those commodities not subject to intervention by the Canadian Wheat Board.

Table IV also reports estimates of the coefficient on the time-to-maturity variable, k, and the associated t-statistics for the test of the null hypothesis of no maturity effect, ($\beta = 0$). The null hypothesis is rejected at approximately the .05 level for 8 of the 14 grains and oilseeds (Chicago and Winnipeg wheat, soybean complex, oats, flaxseed, rye), for all other agricultural, livestock, and energy commodities, and for one metal (copper) and one stock index (major market) commodity.[5] For each of these

[4]When the overall volatility variable, $\sigma^2_{j,\ 6\text{-month}}$, is omitted from the regression equation, the adjusted R^2 values decrease, and the remaining coefficient estimates increase in absolute value, but the signs and significance levels of the coefficient estimates are similar to those reported in Table IV.

[5]Interestingly, only two of the four wheat futures (Chicago and Winnipeg) show a significant maturity effect. Also, of the metals, copper is the commodity whose prices behave the least like a precious metal.

TABLE IV

OLS Regression Results

Regression Model: $\sigma_{j,k}^2 = a + \beta k + \gamma\, \sigma_{j,\text{6-month}}^2 + \varepsilon$

Commodity Type	a	t_a	β	t_β	γ	t_γ	N	$\bar{R}^2$
Grains and oilseeds								
Wheat—Chicago	.00003307	2.78	−.000008750	−3.21	.94643	36.37	726	.648
Wheat—Kansas City	.00001488	1.03	−.000004474	−1.41	.95566	14.67	504	.303
Wheat—Winnipeg	.00001602	1.21	−.000005358	−1.87	.96256	14.11	390	.344
Wheat—Minneapolis	.00001356	1.09	−.000003387	−1.20	.90364	13.10	372	.319
Soybean	.00004491	2.96	−.000011580	−3.31	.92154	30.26	1014	.477
Soybean oil	.00002884	2.31	−.000007370	−2.69	.93950	46.70	1164	.653
Soybean meal	.00006442	3.39	−.000016420	−3.60	.92427	42.37	164	.608
Corn	.00001350	1.30	−.000003183	−1.32	.92789	31.72	726	.581
Oats	.00009752	4.94	−.000020280	−5.37	.84274	17.66	552	.381
Barley	.00001252	0.72	−.000004146	−1.08	.96206	13.47	390	.317
Flaxseed	.00002393	1.56	−.000006190	−2.09	.92911	12.82	360	.317
Rapeseed	.00002946	2.06	−.000004938	−1.70	.82180	12.48	366	.300
Rye	.00004598	2.33	−.000012080	−3.12	.89909	11.49	360	.280
Rough rice	−.00000125	−0.06	−.000000919	−0.18	.94961	19.29	216	.633
Other agricultural								
Cocoa	.00007766	2.94	−.000021500	−4.64	.95508	16.08	366	.435
Coffee	.00011620	4.96	−.000031900	−6.67	.92591	18.76	594	.399
Sugar	.00030750	4.52	−.000091980	−6.41	.97457	19.85	672	.392
Orange juice	.00004466	2.75	−.000009300	−2.81	.87085	18.61	726	.327
Cotton	.00003347	3.21	−.000008931	−3.97	.94292	30.86	612	.613
Lumber	.00002466	1.48	−.000007875	−2.21	.96407	21.99	690	.416
Livestock								
Feeder cattle	.00001411	3.21	−.000003872	−4.23	.95057	31.21	762	.565
Live cattle	.00002249	4.04	−.000005433	−4.69	.90420	28.26	642	.561
Live hog	.00001666	1.77	−.000004019	−1.98	.93819	40.46	972	.628
Pork bellies	.00009433	5.19	−.000026750	−8.32	.94840	28.33	696	.556
Energy								
Crude oil	.00017660	3.20	−.000052280	−3.89	.98895	22.43	696	.426
Heating oil	.00010460	3.24	−.000030950	−4.01	.94821	24.90	948	.401
Unleaded gas	.00013470	3.07	−.000038580	−3.76	.93499	19.21	576	.399
Liquid propane	.00027820	2.83	−.000068140	−2.85	.71666	12.63	372	.309
Metals								
Gold	.00001914	1.13	−.000005825	−1.46	.93433	26.82	672	.517
Silver	.00002218	1.08	−.000004021	−0.90	.91531	31.29	732	.572
Palladium	.00014020	3.70	−.000009815	−1.15	.53819	9.74	252	.273
Platinum	.00002882	1.14	−.000007818	−1.40	.93976	26.19	492	.583
Copper	.00002692	1.60	−.000007167	−1.93	.94555	33.70	642	.640
Stock index								
S&P 500	.00000421	0.06	−.000001598	−0.08	.95737	8.00	264	.191
Major market	.00011680	2.53	−.000030300	−2.60	.44769	9.68	474	.172
NYSE composite	.00000586	0.08	−.000002187	−0.12	.95481	8.02	264	.192

TABLE IV (Continued)

OLS Regression Results
Regression Model: $\sigma^2_{j,k} = \alpha + \beta k + \gamma\, \sigma^2_{j,\text{6-month}} + \varepsilon$

Commodity Type	α	t_α	β	t_β	γ	t_γ	N	$\bar{R}^2$
Interest rate								
Eurodollar	−.00000018	−0.72	.000000105	1.75	.77513	15.27	264	.471
T-bill	.00000007	0.32	−.000000021	−0.42	.95185	44.70	414	.829
T-bond	.00000152	0.33	−.000000581	−0.57	.96439	27.50	372	.670
Currency								
Australian dollar	.00000659	1.11	−.000001341	−1.15	.84590	7.98	150	.297
British pound	−.00000228	−0.56	.000000643	0.77	.95510	19.29	426	.466
Canadian dollar	.00000014	0.16	−.000000070	−0.43	.96792	12.43	384	.285
Deutschemark	.00000048	0.12	−.000000145	−0.19	.95204	17.61	426	.420
Japanese yen	−.00000177	−0.36	.000000619	0.72	.93704	12.41	384	.285
Swiss franc	.00000289	0.60	−.000000548	−0.62	.93806	17.21	426	.409

commodities, the sign on β is negative as expected, that is, the monthly variance of futures returns increases as the time to maturity decreases, holding all else constant. In fact, only 3 of the 45 commodities have positive estimates of β, and these 3 estimates are insignificantly different from zero.

The last column of Table IV reports the adjusted R^2 for each commodity's regression. The reported values show the model in eq. (3) has good explanatory power for all but the stock index commodities. Overall, the results in Table IV indicate the year effect is significant for all commodities, and after controlling for this effect, the maturity effect has a significant influence on the volatility of futures returns for some, but not all, commodities. The affected commodities are those that experience seasonal demand or supply (agriculturals and energy), but not those for which the cost-of-carry model works well (precious metals and financials).

Besides the year effect, another source of nonstationarity in futures prices is the contract-month effect, which refers to random shocks to futures prices arising because futures contracts mature in different months relative to, say, harvest time. A further source of futures price volatility is the calendar-month effect, which refers to the seasonality within a year of the demand for or supply of a commodity. The effects of contract month and calendar month are controlled for and tested by extending the regression analysis as shown in eq. (4). Table V presents coefficient estimates and t-statistics from the extended regression in eq. (4). The table also reports F-statistics from eq. (5), as well as the asso-

TABLE V

OLS Regression and Tests of Contract-Month and Calendar-Month Effects
Regression Model: $\sigma^2_{j,k} = \beta k + \gamma \sigma^2_{j,6\text{-month}} + \Sigma \delta_i C_{j,k,i} + \Sigma \theta_m M_{j,k,m} + \varepsilon$

						Contract Month and Calendar Month Effect H_0: $\delta_i = 0, \theta_m = 0 \; \forall$ i,m		Contract Month Effect only H_0: $\delta_i = 0 \; \forall$ i		Calendar Month Effect Only H_0: $\theta_m = 0 \; \forall$ m	
Commodity Type	β	t_β	γ	t_γ	$\bar{R}^2$	*F-Ratio*	*Pr > F*	*F-Ratio*	*Pr > F*	*F-Ratio*	*Pr > F*
Grains and oilseeds											
Wheat—Chicago	−.000005971	−2.11	.94634	37.11	.667	2.12	.0211	3.14	.0082	5.21	.0000
Wheat—Kansas City	−.000001718	−0.53	.95857	14.37	.340	2.31	.0118	2.56	.0268	4.34	.0000
Wheat—Winnipeg	−.000006385	−2.23	.95725	12.23	.374	1.27	.2461	1.85	.0878	3.53	.0002
Wheat—Minneapolis	−.000001754	−0.61	.89629	12.77	.349	1.67	.0857	1.51	.1853	3.13	.0008
Soybean	−.000003677	−1.10	.92163	32.12	.561	4.46	.0000	5.50	.0000	21.05	.0000
Soybean oil	−.000004867	−1.81	.94071	48.73	.686	3.10	.0006	3.14	.0010	13.96	.0000
Soybean meal	−.000009330	−2.15	.92327	45.12	.667	4.18	.0000	4.47	.0000	22.15	.0000
Corn	−.000004210	−2.03	.90021	33.03	.655	9.44	.0000	10.65	.0000	15.99	.0000
Oats	−.000015770	−4.32	.83068	17.21	.480	6.18	.0000	8.08	.0000	11.89	.0000
Barley	−.000008036	−2.21	.95556	12.05	.414	2.38	.0098	3.56	.0019	7.53	.0000
Flaxseed	−.000006106	−2.11	.91628	11.64	.381	1.85	.0510	2.68	.0150	4.50	.0000
Rapeseed	−.000006669	−2.35	.79431	11.78	.410	2.91	.0016	2.92	.0136	7.87	.0000
Rye	−.000010080	−2.64	.90266	9.38	.340	3.45	.0002	3.26	.0068	4.26	.0000
Rough rice	−.000000549	−0.10	.94683	19.10	.636	0.32	.9766	0.42	.8672	1.78	.0660
Other agricultural											
Cocoa	−.000022040	−4.77	.95590	16.52	.495	3.07	.0009	3.08	.0097	5.55	.0000
Coffee	−.000032640	−6.83	.92873	19.22	.459	4.80	.0000	4.92	.0001	7.93	.0000
Sugar	−.000087130	−5.83	.97300	19.41	.404	2.37	.0093	2.37	.0283	2.37	.0092
Orange juice	−.000009181	−3.09	.87474	20.88	.505	18.90	.0000	8.11	.0000	24.09	.0000
Cotton	−.000010190	−4.59	.94396	31.80	.604	2.21	.0161	2.94	.0124	5.91	.0000
Lumber	−.000008958	−2.40	.96279	21.73	.413	0.57	.8367	0.28	.9443	1.45	.1542

TABLE V (Continued)

OLS Regression and Tests of Contract-Month and Calendar-Month Effects

Regression Model: $\sigma^2_{j,k} = \beta\, k + \gamma\, \sigma^2_{j,6\text{-month}} + \Sigma\, \delta_i C_{j,k,i} + \Sigma\, \theta_m M_{j,k,m} + \varepsilon$

						Contract Month and Calendar Month Effect H_0: $\delta_i = 0$, $\theta_m = 0$ $\forall$ i,m		Contract Month Effect only H_0: $\delta_i = 0\ \forall$ i		Calendar Month Effect Only H_0: $\theta_m = 0\ \forall$ m	
Commodity Type	β	t_β	γ	t_γ	$\bar{R}^2$	*F-Ratio*	$Pr > F$	*F-Ratio*	$Pr > F$	*F-Ratio*	$Pr > F$
Livestock											
Feeder cattle	−.000003800	−4.01	.94966	31.24	.579	1.55	.1174	1.83	.0683	3.79	.0001
Live cattle	−.000006464	−5.60	.90037	28.43	.581	1.78	.0609	1.70	.1057	4.13	.0000
Live hog	−.000003604	−1.75	.93852	41.60	.654	2.31	.0111	2.44	.0175	7.61	.0000
Pork bellies	−.000008668	−0.37	.95132	28.90	.600	3.62	.0001	4.97	.0002	9.06	.0000
Energy											
Crude oil	−.000054700	−4.14	.98728	22.47	.448	0.67	.7483	0.67	.7483	4.38	.0000
Heating oil	−.000031000	−4.14	.95091	25.43	.436	0.87	.5606	0.87	.5606	7.34	.0000
Unleaded gas	−.000038580	−3.92	.93559	19.78	.445	0.53	.8663	0.53	.8663	6.12	.0000
Liquid propane	−.000071630	−3.32	.71911	12.30	.435	3.17	.0007	3.17	.0007	9.78	.0000
Metals											
Gold	−.000003555	−0.88	.93989	27.59	.547	3.08	.0008	2.21	.0250	4.89	.0000
Silver	−.000007320	−1.57	.91397	31.31	.575	0.53	.8682	0.22	.9715	1.23	.2707
Palladium	−.000005751	−0.60	.53295	9.60	.289	2.80	.0027	1.56	.1860	1.61	.1120
Platinum	−.000003641	−0.58	.93725	26.45	.599	2.95	.0013	0.82	.5368	3.39	.0003
Copper	−.000009540	−2.51	.95443	34.10	.650	2.26	.0134	0.91	.4984	3.26	.0004
Stock index											
S&P 500	.000003096	0.15	.95625	8.00	.237	0.25	.9907	0.49	.7453	2.90	.0019
Major market	−.000031980	−2.84	.45846	9.54	.233	0.64	.7825	0.64	.7825	5.34	.0000
NYSE composite	−.000003262	−0.16	.95254	8.01	.241	0.26	.9888	0.52	.7203	3.00	.0013

TABLE V (Continued)

OLS Regression and Tests of Contract-Month and Calendar-Month Effects
Regression Model: $\sigma^2_{j,k} = \beta k + \gamma \sigma^2_{j,6\text{-month}} + \Sigma \delta_i C_{j,k,i} + \Sigma \theta_m M_{j,k,m} + \varepsilon$

						Contract Month and Calendar Month Effect $H_0: \delta_i = 0, \theta_m = 0 \; \forall$ i,m		Contract Month Effect only $H_0: \delta_i = 0 \; \forall$ i		Calendar Month Effect Only $H_0: \theta_m = 0 \; \forall$ m	
Commodity Type	β	t_β	γ	t_γ	$\bar{R}^2$	*F-Ratio*	$Pr > F$	*F-Ratio*	$Pr > F$	*F-Ratio*	$Pr > F$
Interest rate											
Eurodollar	.000000104	1.57	.77085	15.62	.504	1.12	.3456	0.63	.6439	2.44	.0086
T-bill	−.000000026	−0.45	.95202	44.81	.830	0.85	.5779	1.29	.2729	1.70	.0796
T-bond	−.000000412	−0.35	.96445	27.54	.671	0.58	.8325	0.07	.9899	1.44	.1595
Currency											
Australian dollar	−.000000791	−0.61	.85761	8.16	.333	1.49	.1505	0.52	.7205	1.76	.0742
British pound	−.000000169	−0.18	.95488	19.31	.470	0.79	.6427	0.37	.8312	1.68	.0841
Canadian dollar	−.000000086	0.47	.96848	12.59	.303	2.33	.0112	0.79	.5309	2.40	.0092
Deutschemark	−.000000223	−0.26	.95237	17.67	.426	1.20	.2877	0.45	.7743	1.73	.0714
Japanese yen	.000000686	0.72	.93799	12.61	.313	2.62	.0043	0.60	.6599	2.96	.0013
Swiss franc	−.000000311	−0.31	.93830	17.20	.409	1.08	.3763	0.52	.7226	1.27	.2462

ciated p-values, for individual and joint tests of the effects of contract month and calendar month.

The F-statistics and p-values for the test of the null hypothesis of no contract-month effect, ($\delta_i = 0 \; \forall \; i$), indicate the null hypothesis is rejected, in general, for agricultural commodities, but not for energy, metals, and financial commodities. This result is expected because agricultural commodities are the only commodities with a crop cycle and with futures contracts that mature in months before the harvest. These findings agree with Milonas and Vora (1985), who reported evidence of a contract-month effect for five agricultural commodities. However, Khoury and Yourougou (1993) concluded the contract month affects only one Canadian grain (barley).

Similar to the results for contract month, Table V shows the null hypothesis of no calendar-month effect, ($\theta_m = 0 \; \forall \; m$), is rejected for nearly all agricultural commodities. Again, these results agree with Milonas and Vora (1985). Anderson (1985) also found evidence of seasonality in seven of eight agricultural futures, and Khoury and Yourougou (1993) found such evidence for four of six Canadian grains and oilseeds.

Unlike the contract month, the calendar month is also an important source of futures returns volatility for energy and stock index commodities. The general results of the test for a calendar-month effect are as expected because agricultural and energy commodities are the commodities that experience seasonal supply or demand. When the effects of calendar month and contract month are tested jointly, the results generally agree with the individual tests.

After controlling for other sources of nonstationarity in futures prices, Table V indicates the overall variance of returns in the six months before expiration continues to have a significant and positive relationship to the monthly returns variance for all 45 commodities. Again, this result supports the presence of a year effect in which general conditions over an extended period before maturity can affect supply or demand for a commodity.

Concerning the maturity effect, the results from the extended regression in Table V generally agree with the results in Table IV. The estimates of the time-to-maturity coefficient (β) and the associated t-statistics indicate a significant negative relationship between time-to-maturity and futures returns volatility for nine of the grains and oilseeds (Chicago and Winnipeg wheat, soybean meal, corn, oats, barley, flaxseed, rapeseed, rye). Similar to these findings, Castelino and Francis (1982) and Milonas (1986) reported a maturity effect for wheat and the soybean complex, but Milonas rejected a maturity effect for corn. Khoury and Yourougou (1993) found support for a maturity effect in wheat, barley, flaxseed, and rye, as well as two other Canadian grains.

Table V also shows a significant maturity effect for all commodities in the other-agricultural category, for two of the four livestock commodities (feeder and live cattle), for all the energy commodities, and for copper and the major market stock index. Similar to these results, Anderson (1985) concluded the maturity effect is significant for live cattle and cocoa, but not for silver. Milonas (1986) found a maturity effect not only for copper, but also for the precious metals of gold and silver. Unlike the results reported in this study, Milonas (1986) found support for the financial commodities of Treasury bills and bonds. Barnhill, Jordan, and Seale (1987) found a maturity effect for Treasury bonds as well; however, when they used a sequence of dummy variables to represent time to maturity, the first dummy variable for the period from 91 to 273 days before maturity was negative but insignificantly different from zero.

Examination of the estimates of β in Table V also reveals only four of the 45 estimates are positive, and these estimates are insignificantly different from zero. Thus, after controlling for several sources of nonstationarity, it appears the volatility of futures prices for certain commodities increases as the time to maturity decreases. Specifically, time to maturity significantly affects futures price volatility for commodities that experience seasonal demand or supply, such as agriculturals and energy, but not commodities for which the cost-of-carry model works well, such as precious metals and financials.

SUMMARY AND CONCLUSIONS

This article examines the issue of volatility in futures prices and investigates the maturity effect, a source of nonstationarity in futures prices arising because prices of futures contracts closer to expiration react more strongly to new information about the underlying commodity than do prices of contracts further from expiration. The dataset includes over 500,000 daily settlement prices from the period, 1969–1992, for 4111 contracts on 45 commodities. The contracts analyzed are drawn from both physical (agricultural, energy, and metals) and financial (stock index, interest rate, and currency) commodities.

Monthly variances of daily futures returns are formed and, across all commodities, approximately 50% of the contracts are found to have a returns variance in any given month that is greater than the returns variance in the previous month, as would be expected if a maturity effect exists. When ratios of the variances are formed to assess the significance of these differences over time, the results are less supportive of a maturity effect; however, the impact of time to expiration varies widely across commodity types.

A multivariate regression analysis yields much stronger support for the maturity effect for several types of commodities. The regression analysis controls for other sources of nonstationarity in futures prices, including the year effect, the calendar-month effect, and the contract-month effect. The year effect, in which general conditions prevailing over an extended period before maturity affect supply or demand, has a significant influence on the volatility of monthly futures returns for all commodities. The contract-month effect is important for agricultural commodities, while the calendar-month effect is important for agricultural commodities, as well as energy and stock index commodities. In general, these results are as expected because agricultural and energy commodities are associated with crop cycles and seasonal supply or demand.

After controlling for these other sources of nonstationarity, the time-to-maturity variable is found to have a significant negative relationship to monthly returns variance for many of the agricultural commodities, for all the energy commodities, and for copper. Time to maturity is not a significant influence for the precious metals and for all but one of the financial commodities. This study, therefore, concludes that the maturity effect is an important source of volatility in futures prices for commodities that experience seasonal demand or supply, but not for commodities for which the cost-of-carry model works well.

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