An ARCH Analysis of the Hedging Performance of

Imminently Maturing Futures Contracts

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Practitioner's Abstract

Hedge ratio estimation studies avoid estimating hedge ratios for imminently maturing futures contracts. This practice reflects the belief that hedgers should also avoid imminently maturing futures contracts because of the maturity effect whereby futures price volatility increases as price uncertainty is resolved at contract expiration. This study first points out that a futures-price volatility increase is neither necessary nor sufficient for reduced hedging effectiveness because hedging effectiveness depends on the cash-futures price correlation. To analyze the hedging performance of imminently maturing futures contracts risk is defined as the conditional variance of profit outcomes. The conditional mean is modeled as Brownian motion. This model was fit to cash and futures price data for corn, cotton, feeder cattle, soybeans, soybean oil, and soybean meal using daily observations from January 1990 through mid-March 2002. Test results indicate that daily futures prices for these commodities follow a random walk while spot prices are predictable. Therefore, zero (for futures prices) and the predicted value (for spot prices) were used as the conditional means in estimating the conditional variances for futures and spot prices. Volatility is analyzed as an ARCH process with a mean that follows a quadratic function of days to maturity. It was found that the quadratic function was significant for all futures contracts with the volatility minimum occurring between 131 and 259 days before contract maturity. The ARCH effects were generally not significant for futures prices while spot price volatility displayed significant ARCH effects. The maturity effect in the futures markets has a dominant influence on the spot-futures correlation so that the effectiveness of hedging tends to decrease as the futures price volatility begins to increase. The effectiveness decline occurs far sooner than the contract selection rules imply.

Keywords: maturity effect, hedging effectiveness, risk management.

Introduction

Hedge ratio estimation studies frequently employ contract selection rules to prevent the futures contract used in the hedge from being too close to maturity when the hedge is closed. These rules are applied by initially specifying the hedge's term. The hedge's term and placement date determine its closure date. The nearby futures contract on the closure date is selected as the hedge vehicle if it matures more than a predetermined number of days (typically two weeks) beyond hedge closure. Otherwise, the next nearest maturity is selected. An alternative procedure that also precludes the use of imminently maturing futures contracts is for the hedge to use the nearest-maturing contract at hedge closure so long as the closure date is not in the contract's maturity month. These rules have been employed in the study of direct hedging (for example, Castelino (1992), and Turvey and Kayak (2003)), process hedging (for example, Fackler and McNew (1993), Dahlgran (2000)), cross hedging (for example, Hayenga and

DiPietre (1982), and Vukina and Anderson (1993)), and optimal hedging with variable hedge ratios (for example, Moschini and Meyers (2002), Haigh and Holt (2002)).[1]

The avoidance of imminently maturing futures contracts in hedging contradicts the notions that futures markets are efficient and that cash and futures prices converge at contract maturity at the delivery location. This is because efficient, convergent futures markets provide riskless hedging if the hedge is liquidated at contract maturity. These contradictory notions are the impetus for this empirical investigation.

The literature cites several reasons for avoiding imminently maturing futures contracts when hedging. These reasons include (1) occasional squeezes in the delivery month might increase basis volatility (Castilino, 1992), (2) futures markets become "thin" and prices become more volatile at contract maturity (Castilino (1992), Haigh and Holt (2002)), (3) futures price volatility increase over the life of the contract because of the maturity effect (Samuelson, 1965), (4) futures price volatility increases (or at least changes) as price uncertainty is resolved at contract expiration (Anderson and Danthine, 1982), (5) avoidance of the delivery process[2] (Hayenga and DiPietre (1982)), and (6) allowance for uncertainty about the hedge's length at hedge placement. However, the author is unaware of any studies that have focused specifically on hedging implications of a price volatility increase associated with imminent maturity as suggested by (1) through (4), or of studies that compare the price volatility of imminently maturing futures contracts to the same-period price volatility of the next nearest maturity.

Volatility-related contract selection rules might be justified by the maturity effect. This notion was first presented by Samuelson (1965) who argued that if spot prices follow an ARIMA(1,0,0) process, and if the futures price equals the expected contract-maturity spot price, then the variance of futures price changes must increase as the contract approaches expiration. The intuition behind Samuelson's model is (Galloway and Kolb, 1996), "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." Miller (1979) interprets Samuelson's result as "the assumption that futures prices follow a martingale means that the futures price is the expected spot price, and the assumption of a mean-reverting spot process implies, in turn, that the longer the life of the asset, the greater the extent at which spot price (hence futures price) fluctuations will be offsetting."

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1 Even studies of the determinants of future-price volatility sometimes set aside observations at the very end of the contract's life (Grammatikos and Saunders(1986), Chen, et. al (1999), Koury and Yourougou (1993), and Goodwin and Schnepf (2000)).

2 We note three important considerations relating to delivery avoidance. First, for cash-settled contracts delivery process avoidance is a minor motive because delivery in this case is a financial transaction. Second, we note that hedgers deal in the cash commodity so making or taking delivery is part of the hedger's normal operations. The costs of making/taking delivery are not nearly so high for hedgers as for speculators. However, delivery to/from an out-of-position location can be costly. Third, during our sample period delivery involves negotiable warehouse receipts. The negotiability of these warehouse receipts can be used to make delivery to/from an out-of-position location a financial transaction, which is less costly (though not costless) than physical delivery of the commodity.

Rutledge (1979) uses slightly different assumptions to show that if the spot price follows an ARIMA(1,1,0) process, and if the futures price equals the expected contract-maturity spot price, then the variance of futures price changes must decrease if the autoregressive coefficient is between zero and one and will be constant if the autoregressive coefficient is zero. Miller (1979) demonstrates that if spot prices follow an ARIMA(2,0,0) process and if the futures price equals the expected contract-maturity spot price, then the futures price volatility depends on the values of the ARIMA parameters. Finally, Anderson and Danthine (1983) show that when futures and cash prices are simultaneously determined, futures price volatility depends on the amount of supply and demand uncertainty that is resolved in a particular period. Hence, volatility may increase or decrease as delivery approaches depending on when new information flows into the market. Therefore, according to Rutledge, Miller, and Anderson and Danthine, the existence, form, and magnitude of the maturity effect is an empirical issue.

The maturity effect has been investigated in several studies as summarized in table 1. The last column indicates that a maturity effect is frequently, though not universally, detected. This mixture of results depends on the methodologies employed, the markets analyzed, the time period of observation, the periodicity of the data, as well as experimental error. More specifically, the earlier studies analyze unconditional monthly variances (rather than conditional variances) of daily logarithmic price changes. Second, a few studies employ GARCH models, and fewer still examine daily volatility with GARCH models. Most of the studies that employ GARCH methods focus on weekly volatility. Third, none of the studies examine the implications of the maturity effect for hedging effectiveness.

Hedging effectiveness is defined by Ederington (1979) as

$$e = 1 - V(\pi_h)/V(\pi_u) \tag{1a}$$

where e represents hedging effectiveness, π_h is the profit from hedged cash market positions and π_u is profit from unhedged cash market positions. In the single-commodity risk-minimization case, this expression reduces to

$$e = (\rho_{\Delta s,\Delta f})^2 = (\sigma_{\Delta s,\Delta f})^2 / (\sigma^2_{\Delta s}\, \sigma^2_{\Delta f}). \tag{1b}$$

where $\rho_{\Delta s,\Delta f}$ is the correlation between futures and cash price changes, $\sigma_{\Delta s,\Delta f}$ is the corresponding covariance, $\sigma^2_{\Delta f}$ is futures price volatility, and $\sigma^2_{\Delta s}$ is the volatility of the cash price. (1b) shows that while an increase in futures price volatility will reduce effectiveness, *ceteris paribus*, the behavior of the covariance between futures and cash price changes, and the volatility of cash prices are also important. Several recent studies have examined the implications of nonconstant variances and covariances for variable hedge ratios (Moschini and Myers (2002), Poomimars et. al (2003), Dawson et. al (2000), Haigh and Holt (2002)), but none have specifically examined the effectiveness of hedging in imminently maturing futures contracts.

Table 1. Summarization of previous maturity effect studies.[a]

Author(s)	Contracts[b]	Time period[c]	Results *vis a vis* the maturity effect (ME)
Rutledge(1976)	Sept 69 KC wheat, May 71 soybean oil Sept 69 NY silver, Dec 70 cocoa	1st & last 3 mos (daily)	Wheat, soybean oil: No evidence of ME. Silver, cocoa: Supportive of ME.
Miller (1979)	June and Dec live cattle	Jan 1965-Jun 72 (mo vol)	Supportive.
Castelino and Francis (1982)	wheat and soybeans	1960-71	Supportive.
Anderson (1985)	KC wheat, CBT wheat, corn, oats, soybeans soybean oil, live cattle, silver, and cocoa	1966-80 (mo vol)	Supportive, but seasonal effect more important
Milanos (1986)	wheat corn, soybeans, soybean meal, soybean oil, GNMA CDR, T-bills T-bonds, copper, gold, silver	1972-83 (mo vol)	Supportive for all commodities except corn.
Grammatikos and Saunders (1986)	IMM BP, C$, DM, SF, yen	3/78-3/83 daily last 6 mos of trading	ME insignificant.
Barnhill, et al. (1987)	T-bonds - 6 nearest maturities	8/77-12/84 (wkly vol)	ME significant.
Kenyon et al. (1987)	Mar soybeans, Mar corn, Jul wheat, Apr cattle, Apr hogs	1974-83 (mo vol)	Grain volatility affected by season, not so for livestock. ME and seasonal effects not separable.
Streeter and Tomek (1992)	Nov and Mar soybeans	76-86 (mo vol)	Volatility increases at decreasing rate as maturity nears.
Serletis (1992)	crude oil, heating oil, gasoline	1987-90 (da vol)	Trading volume more important than ME.
Khoury and Yourougou (1993)	Winnipeg barley, oats, flaxseed, rye, feed wheat and canola (nearby)	3/80-7/89 (mo vol)	Volatility influenced by year, calendar month contract month, maturity and trading session
Galloway and Kolb (1996)	45 commodities, 4,111 maturities	1969-92 (mo vol for each of 6 mos preceding expiration	ME significant for commodities that experience seasonal supply and demand patterns, but not for those for which the cost-of-carry model works well. ME secondary to seasonality.

Table 1 (continued). Summarization of previous maturity effect studies.[a]

Author(s)	Contracts[b]	Time period[c]	Results *vis a vis* the maturity effect (ME)
Hennessy and Wahl (1996)	corn, soybeans, CBT wheat, KC wheat, Mpls wheat	1985-94 (mo vol)	ME insignificant.
Han et al. (1999)	Nearby IMM BP, C$, DM, Yen	1990-97 (tick vol)	ME insignificant.
Chen et al. (1999)	Nikkei-225 Index, spot and nearby basis	11/24/88-6/6/96 (da vol)	Volatility decreases as contract matures.
Goodwin and Schnepf (2000)	Dec CBT corn, Sep MPLS wheat	1986-97, vol of wkly avg	ME significant for corn, but not for wheat.
Moosa and Bollen(2001)	S&P 500 Index	1993-95 da vol from trades	ME insignificant
Arago and Fernandez (2002)	IBEX-35 stock index spot and nearby futures	1/4/93-12/17/99 (daily vol)	Increased volatility during last week of trading.

a/ This table embellishes and extends a similar table constructed by Moosa and Bollen.
b/ All available maturities unless indicated otherwise.
c/ Daily unless indicated otherwise

The overall objective of this study is to determine whether a pre-maturity volatility increase justifies avoidance of hedging in imminently maturing futures contracts, or whether the reasons for avoiding imminently maturing futures contracts should more correctly focus on delivery avoidance and hedge term uncertainty. This study extends the literature by applying the ARCH methodology to daily data to analyze the conditional volatility and correlation of a set of futures contracts near their maturity. We use a conditional cash-futures price-correlation model to compare the effectiveness of hedging in the imminently maturing futures contract to the effectiveness of hedging in the same period with the next nearest maturity futures contract. We will examine several commodities - corn, soybeans, cotton, and feeder cattle - in order to draw conclusions about the generality of our findings.

The plan for this paper is as follows. First, we define the profit outcomes from hedging so that hedging risk can be defined as the conditional variance of the profit outcome around its expectation at hedge placement. Under empirical results, we discuss the 175,000 observations that will be employed for regression analysis. Next we focus on the estimation of conditional means for the cash and future prices. These conditional means are used to estimate the conditional variances and conditional correlations with time-to-maturity effects.

Empirical Model

Let S_t represent a commodity's cash or spot price at time t, let F_{Tt} represent the price at time t of a futures contract that matures at time T, and let T be a member of the set M_t representing the futures contract maturities trading at time t. Suppose X_s units of a commodity are hedged at time p with X_f units in a futures contract that matures at time T with removal anticipated at time r ($p < r \leq T$). X_s can be positive to indicate a long position spot market position or negative to indicate a short spot market position. X_f likewise indicates long (if positive) or short (if negative) futures market positions. The hedge's return is

$$\Pi = X_s (S_r - S_p) + X_f (F_{Tp} - F_{Tr}) \tag{2a}$$

Let b represent the hedge ratio, $b = X_f / X_s$, so the return realized per long unit of the commodity hedged is[3]

$$\pi = (S_r - S_p) + b (F_{Tp} - F_{Tr}) \tag{2a}$$

Let Ω_p represent the information available at hedge placement. Current spot and futures prices are known at hedge placement, so the return anticipated per unit at hedge placement is

$$E(\pi|\Omega_p) = - S_p + b F_{Tp} + E(S_r |\Omega_p) - b E(F_{Tr} |\Omega_p) \tag{2b}$$

The risk of hedging is due to differences between realized and anticipated returns and is measured as the variance of (2a) about its conditional expectation (2b), i.e.,

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3 $\pi = \Pi / X_s$ is profit per unit of physical commodity for long spot market positions ($X_s > 0$) and is the loss per unit of physical commodity for short shot market positions ($X_s < 0$).

$$\text{Risk} = V(\pi \,|\Omega_p) = E\{ [S_r - E(S_r \,|\Omega_p)] - b\,[F_{Tr} - E(F_{Tr} \,|\Omega_p)] \}^2 \tag{3a}$$

This gives the well-known results that

$$b^* = \sigma_{0T,r} \,/\, \sigma_{T,r}^{\;2}, \tag{3b}$$

$$V^*(\pi \,|\Omega_p) = \sigma_{0,r}^{\;2}\,(1 - \rho_{0T,r}^{\;2}), \text{ and} \tag{3c}$$

$$e = \rho_{0T,r}^{\;2} = \sigma_{0T,r}^{\;2} \,/\, \sigma_{T,r}^{\;2}\, \sigma_{0,r}^{\;2} \tag{3d}$$

where b* is the risk-minimizing hedge ratio, $\sigma_{0T,r} = \text{Cov}(S_r,F_{Tr} \,|\Omega_p)$, $\sigma_{T,r}^{\;2} = V(F_{Tr} \,|\Omega_p)$, $\sigma_{0,r}^{\;2} = V(S_r \,|\Omega_p)$, $V^*(\pi \,|\Omega_p)$ is the minimized value of the conditional variance, $\rho_{0T,r}$ represents the conditional correlation between the cash price and the T-maturity futures contract price, and e is the effectiveness of hedging in the T-maturity futures contract.

The risk of hedging with imminently maturing futures contracts depends on the behavior of the components of (3d) as $r \rightarrow T$. The maturity effect refers to the behavior of $\sigma_{T,r}$ and is only part of the more comprehensive relationship that also includes the seasonal behavior of the variance of the spot price and the behavior of the spot-futures price correlation as contracts approach maturity. Estimation focuses on the temporal behavior of all three components, σ_{0r}, σ_{Tr} and $\rho_{0T,r}$.

Price behavior is represented with the Brownian motion model (Hull, p. 71). Let

$$(S_{t+\Delta t} - S_t) \,/\, S_t \equiv \Delta S_t / S_t = \mu_{0t}\, \Delta t + \varepsilon_{0t} \sqrt{\Delta t}\text{ , and} \tag{4a}$$

$$(F_{T,t+\Delta t} - F_{Tt}) \,/\, F_{Tt} \equiv \Delta F_{Tt} / F_{Tt} = \mu_{Tt}\, \Delta t + \varepsilon_{Tt} \sqrt{\Delta t}\text{ , for } T \in M_t \text{ and } t=1,2, \ldots N. \tag{4b}$$

Thus, ΔS_t and ΔF_{Tt} represent changes in the spot and futures prices (contract maturity at T) that occur in a short time interval (Δt), and ε_{0t} and ε_{Tt} represent normally distributed random errors.

The parameters μ_{0t} and μ_{Tt} represent respectively the proportional drift in the spot and T-maturity futures prices. The time subscripts on μ_{0t} and μ_{Tt} allow the drift to vary through time. If futures markets are efficient, then $F_{Tt} = E(F_{T,t+1} \mid \Omega_t) = E(F_{T,t+2} \mid \Omega_t) = \ldots = E(F_{TT} \mid \Omega_t)$. This implies that $E(F_{T,t+1} - F_{Tt} \mid \Omega_t) = 0$ so that $\mu_{Tt} = 0$. An extensive literature on futures market efficiency exists and many studies conclude that futures markets for various commodities are efficient in the weak form. The argument for market efficiency is that if $\mu_{Tt} > 0$ ($\mu_{Tt} < 0$), then futures market participants will take long (short) positions and profit from the predictable price movements. In our empirical analysis, we will test the notion that futures prices follow a random walk about a systematic drift.

Similar arguments do not apply to spot price behavior. Spot prices are expected to display seasonal patterns based on supply and demand cycles. Seasonal spot price patterns mean that $\mu_{0t} > 0$ for t corresponding to the part of the year when spot prices are expected to increase and $\mu_{0t} < 0$ for t corresponding to the part of the year when spot prices are expected to decrease.

Several sources of price heteroscedasticity are apparent in equations (4a) and (4b). The expectation that larger (smaller) absolute price changes accompany higher (lower) prices is one source of heterscedasticity. Expressing price changes relative to levels controls this source of heterscedasticity.

Holidays and weekends constitute a second source of heteroscedasticity. For example, larger price changes are expected between Friday and Monday than between Monday and Tuesday because over the longer Friday to Monday time interval, more news events and random shocks can occur. This heteroscedasticity due to the uneven spacing of observations is represented by the multiplication of the error term by $\sqrt{\Delta t}$. To control for this source of heteroscedasticity, both sides of (4a) and (4b) are divided by $\sqrt{\Delta t}$ giving

$$\Delta S_t /(S_t \sqrt{\Delta t}) = \mu_{0t} / \sqrt{\Delta t} + \varepsilon_{0t} \quad (5a)$$

$$\Delta F_{Tt} /(F_{Tt} \sqrt{\Delta t}) = \mu_{Tt} / \sqrt{\Delta t} + \varepsilon_{Tt}, \qquad T \in M_t \quad (5b)$$

A third source of heteroscedasticity is due to periodic increases (decreases) in price volatility. Heteroscedasticity of this type is represented by expressing the stochastic terms in (5a) and (5b) as a GARCH(p,q) process where

$$\varepsilon_{Tt} = \zeta_{Tt} \sqrt{h_{Tt}}, \text{ and}$$
$$h_{Tt} = \varphi_{T0} + \sum_{i=1}^{q} \varphi_{Ti} \varepsilon^2_{T,t-i} + \sum_{i=1}^{p} \psi_{Ti} h_{T,t-i}, \text{ for } T = 0 \text{ and } T \in M_t \quad (5c)$$

$T = 0$ represents cash prices and $T \in M_t$ represents the various futures prices. The usual assumptions of a GARCH model are $E(\zeta_{Tt}) = 0$ and $V(\zeta_{Tt}) = 1$ and ζ_{Tt} and h_{Tt} are independent. Accordingly, $E(\varepsilon_{Tt}) = 0$ and $V(\varepsilon_{Tt}) = h_{Tt}$. We also note that the source of cash-futures price correlation is $E(\zeta_{Tt}\, \zeta_{0t}) = \rho_{0T}$ and ρ_{0T} may vary through time.

The systematic behavior of volatility as time to maturity diminishes is represented with

$$\varphi_{T0} = \theta_{T0} + \theta_{T1} (T\text{-}t) + \theta_{T2} (T\text{-}t)^2 \quad (5d)$$

where T-t is days to contract maturity. The time to maturity associated with the volatility extremum is found by setting $\partial\varphi_{T0} / \partial(T\text{-}t) = 0$ and solving for $(T\text{-}t)^* = -\theta_{T1} / 2\theta_{T2}$. Furthermore, $\partial\varphi_{T0} / \partial(T\text{-}t) \mid_{(t=T)} = \theta_{1T}$ indicates the direction of volatility movement as $t \rightarrow T$. Thus, if $\theta_{1T} > 0$ ($\theta_{1T} < 0$) then volatility is decreasing (increasing) as $(T\text{-}t) \rightarrow 0$.

The errors of (5a) and (5b) are also used to assess cash-futures price correlation behavior as a function of time to maturity. (5c) results in a correlation model of the form

$$\varepsilon_{Tt}\varepsilon_{0t} = \rho_{0T,t} \sqrt{h_{Tt} h_{0t}} + \xi_{0T,t} \quad (6)$$

where $\rho_{0T,t} = \lambda_{T0} + \lambda_{T1} (T\text{-}t) + \lambda_{T2} (T\text{-}t)^2 + \lambda_{T2}\, \rho_{0T,t-1}$.

Table 2. Summary of cash prices (Jan 1, 1990 to Mar 18, 2001).

Commodity	units	Obs	Avg	Std Dev	Min	Max
Corn - No 2 yellow, Cent. IL	cts/bu	3,080	255.59	58.95	161.75	558.50
Cotton - 1 $^{1}/_{16}$ str lw-mid, Memphis	cts/lb	3,075	65.10	15.32	26.27	112.84
Feeder cattle - steers, Oklahoma City	$/cwt	3,077	86.77	11.70	54.25	109.88
Soybeans - #1 yellow, Cent. IL	cts/bu	3,080	582.34	103.11	387.50	882.50
Soymeal - 48% protein, Decatur, IL	$/tn	3,080	185.72	37.31	123.00	314.50
Soyoil - crude, Decatur IL	cts/lb	3,080	21.53	4.56	11.83	31.57

Empirical Results

The data used for this analysis come from the Bridge/Commodity Research Bureau InfoTech data source (Bridge/CRB 2002). This commercially available data set contains daily open, high, low, and settlement futures prices and spot prices for a wide variety of commodities from the early 1900s to the present. Our sample uses daily cash prices for the period from January 2, 1990 through March 18, 2002 were obtained for corn (No 2 yellow, central Illinois), cotton (1 1/16 str lw-mid, Memphis), feeder cattle (steers, Oklahoma City), soybeans (#1 yellow, central Illinois), soybean oil (crude, Decatur Illinois), soybean meal (48% protein, Decatur, Illinois). These commodities were selected to include a mix of storable seasonally produced commodities (cotton, corn, and soybeans) non-storable commodities (feeder cattle) and commodities with processing linkages (soybeans, soy meal and soy oil). Corn and soybean futures markets have a long history, economic importance and broad research base. Cotton and feeder cattle are chosen because of their economic importance to agriculture in the author's home state. The time span selected covers 4,458 calendar days, or 3,184 weekdays. Additional observations were lost because of holidays. Table 2 summarizes these data.

Daily futures settlement prices for the same time period for corn (Chicago Board of Trade, CBT), cotton (New York Cotton Exchange, NYCE), feeder cattle (Chicago Mercantile Exchange, CME), soybeans (CBT), soybean meal (CBT) and soybean oil (CBT) were also obtained from the Bridge/Commodity Research Bureau InfoTech data source. These data form individual time series and are summarized in table 3. Table 3 indicates, for example, that corn futures prices were obtained for 77 different maturities, that one maturity (a January maturity) had only one price quote during the period and one contract (a December maturity) had 752 price quotes. The very short time series are due to contracts expiring just after the start of the sample period or contracts beginning to trade just before the end of the sample period. Furthermore, the March, May, July, September and December contracts seem to have traded each year while the January and November maturities were not.

Table 3. Summary of futures price series (Jan 1, 1990 to Mar 18, 2001).

Commodity	Maturity	No. of Series	Obs	Series Lengths ---------5 Smallest--------					Largest
Corn (CBT)	**All**	**77**	**26,610**	**1**					**752**
	Jan	3	524	1	191				331
	Mar	15	4,550	2	56	118	307	328	379
	May	14	4,264	53	98	287	326	330	358
	Jul	15	5,524	54	140	194	335	335	563
	Sep	13	4,141	182	246	324	332	333	370
	Nov	2	462	166					296
	Dec	15	7,222	52	246	262	397	400	752
Cotton(NYCE)	**All**	**76**	**26,587**	**3**					**497**
	Mar	15	5,254	3	47	245	289	352	497
	May	14	5,297	88	190	335	364	369	493
	Jul	14	5,383	130	161	340	370	370	496
	Aug	3	70	12	16				42
	Sep	2	22	10					12
	Oct	14	5,248	99	194	131	334	347	497
	Dec	14	5,304	63	235	307	369	370	497
Feeder Cattle (CME)	**All**	**105**	**23,935**	**18**					**258**
	Jan	14	2,967	18	30	163	242	246	257
	Mar	13	3,000	62	202	238	241	245	258
	Apr	13	2,964	81	222	225	226	232	252
	May	13	3,022	101	200	239	240	243	252
	Aug	13	3,033	132	169	226	244	246	256
	Sep	13	2,973	116	188	215	230	233	252
	Oct	13	2,980	96	207	212	230	231	256
	Nov	13	2,996	77	221	227	233	237	257
Soybeans(CBT)	**All**	**98**	**30,486**	**1**					**705**
	Jan	14	3,776	15	66	258	268	289	336
	Mar	14	3,961	56	66	292	299	307	336
	May	14	3,914	43	98	289	300	301	337
	Jul	15	5,335	1	75	140	296	326	642
	Aug	13	3,451	163	191	265	266	269	307
	Sep	13	3,549	144	182	249	270	286	325
	Nov	15	6,500	1	226	247	312	274	705

Table 3. Continued.

Soymeal (CBT)	**All**	**110**	**30,335**	**15**					**436**
	Jan	14	3,421	15	105	230	253	255	315
	Mar	14	3,381	56	60	229	251	266	297
	May	14	3,641	52	98	258	263	287	308
	Jul	14	4,052	140	201	273	281	292	363
	Aug	13	3,571	163	247	260	267	269	329
	Sep	13	3,672	182	205	274	274	278	351
	Oct	14	4,024	189	205	247	272	283	355
	Dec	14	4,573	189	246	247	316	324	436
Soyoil (CBT)	**All**	**110**	**32,077**	**15**	**461**				
	Jan	14	3576	14	102	260	263	267	315
	Mar	14	3750	56	101	280	282	292	315
	May	14	3960	98	100	292	293	300	334
	Jul	14	4352	140	210	284	316	317	375
	Aug	13	3740	163	209	274	285	300	340
	Sep	13	3834	182	208	279	286	288	361
	Oct	14	4164	34	205	284	290	293	413
	Dec	14	4701	48	246	284	315	329	461

Conditional means - futures prices. Estimating the conditional variance (or volatility) of futures prices requires first estimating the conditional mean. We start by focusing on the notion that in (4b), $\mu_{Tt} = 0$. Testing this notion using only historical prices is equivalent to testing whether the selected futures markets are weak form efficient. The Dickey-Fuller (1979, 1981) test for a random walk forms the foundation for this test. A Dickey-Fuller model with a drift for the T-maturity futures contract price series is

$$\Delta F_{Tt} = a_T + \gamma_T F_{Tt} + e_{Tt}, \text{ for } T \in M_t, t = 1,2, ...N_T. \tag{7a}$$

where ΔF_{Tt} is $F_{T,t+1} - F_{Tt}$. If the hypothesis that $a_T = 0$ is rejected, then the futures price series drifts so that the notion that $\mu_{Tt} = 0$ in (4b) must be rejected. If the hypothesis that $\gamma_T = 0$ is rejected, then the futures price series does not follow a random walk. Alternatively stated, if futures prices don't follow a random walk, then period-to-period futures price changes are predictable based on the information in F_{Tt} so the notion of weak-form futures market efficiency must be rejected.

In (4b) the dependent variable is the price change relative to the initial level while in (7a) the dependent variable is simply the price change. Transforming (7a) into the specification in (4b) results in[4]

[4] The model $\Delta F_{Tt} / (\sqrt{\Delta t}\, F_{Tt}) = a_T (1/\sqrt{\Delta t}\, F_{Tt}) + \gamma_T (1/\sqrt{\Delta t}) + b_T (t / \sqrt{\Delta t}\, F_{Tt}) + (e_{itT} / F_{Tt})$ was also estimated. Our conclusions are unaffected by the inclusion of the trend.

$$\Delta F_{itT} / (\sqrt{\Delta t}\, F_{Tt}) = a_T\, (1/\sqrt{\Delta t}\ \ F_{Tt}) + \gamma_T\, (1/\sqrt{\Delta t}) + (e_{Tt} / F_{Tt}) \qquad (7b)$$

where a_T still represents the drift in the Dickey-Fuller model and γ_T still represents non random walk behavior. This specification controls for unequally spaced observations and larger price changes at higher prices and still permits testing for a random walk with a drift.

(7b) was fit to each time series described in table 3 and Dickey-Fuller test statistics for the hypothesis $\gamma_T = 0$ and the joint hypothesis $a_T = \gamma_T = 0$ were computed. The critical value of these test statistics depends on the number of observations (Dickey and Fuller, 1981), which varies by contract (table 3) so the resulting test statistics are not perfectly comparable. However, if samples of less than 80 are ignored, then the critical values are nearly the same so a nearly accurate depiction of test conclusions can be obtained by comparing the test results to a single critical value. Figure 1 summarizes the results of these two tests. Using the Dickey-Fuller 5% critical values of -2.89 for τ_μ (n=100 and α=0.05) and 4.71 for Φ_1 (n=100 and α=0.05) establishes rejection the regions. These regions are slightly too large (too small) for samples with more than (fewer than) 100 observations. In figure 1, 32 of the 540 (5.9%) statistics fall in the 5% rejection region for H_0: $a_T = 0$. This is five more rejections than expected. The χ^2 goodness of fit statistic of 0.973 has the probability of a larger value of 0.324 so the null hypothesis of a random walk is not rejected for the sample of all contracts selected. It is noted however that the hypothesis was disproportionately rejected for feeder cattle. Likewise, 22 (4.1%) of the 540 tests of H_0: $a_T = \gamma_T = 0$ were rejected. This is fewer than expected and again, a disproportionate number of rejections occurred for feeder cattle. Based on these results, we proceed under the assumption that the futures prices for the commodities studied follow a random walk without a discernable drift term.

Conditional means - spot prices. Suppose that seasonal supply and demand patterns consisting of a period of relative surplus and another period of relative scarcity generate an annual price cycle. A cubic function, which can have a local maximum and a local minimum, is used to represent the expected spot price path over this cycle. This function is expressed as

$$E(S_{t+\tau} \mid \Omega_t) = S_t\, (\alpha_{0t} + \alpha_{1t}\, \tau + \alpha_{2t}\, \tau^2 + \alpha_{3t}\, \tau^3) \qquad (8a)$$

where $0 \le \tau \le 365$ and α_{0t}, α_{1t}, α_{2t}, and α_{3t} are unknown parameters. The current spot price lies on this path because when $\tau = 0$, $E(S_t) = S_t$. Hence, α_{0t} must be unity so (8a) becomes

$$[E(S_{t+\tau} \mid \Omega_t) - S_t\,] / S_t = \alpha_{1t}\, \tau + \alpha_{2t}\, \tau^2 + \alpha_{3t}\, \tau^3 \qquad (8b)$$

Notions of efficiency and price convergence imply that futures prices reflect current expectations of the spot price at contract maturity. More specifically, if arbitrage causes futures and spot prices to converge at contract maturity, then $E(S_T \mid \Omega_t) = E(F_{TT} \mid \Omega_t)$. If futures markets are efficient, then $F_{Tt} = E(F_{TT} \mid \Omega_t)$. Combined, efficiency and convergence give $F_{Tt} = E(S_T \mid \Omega_t)$ so that the currently quoted futures price represents the currently anticipated spot price at contract-maturity. Under this combination F_{Tt} replaces $E(S_{t+\tau})$ and T - t (i.e., days to maturity) replaces τ. Thus, the parameters (α_{1t}, α_{2t}, α_{3t}) are estimated for each day using

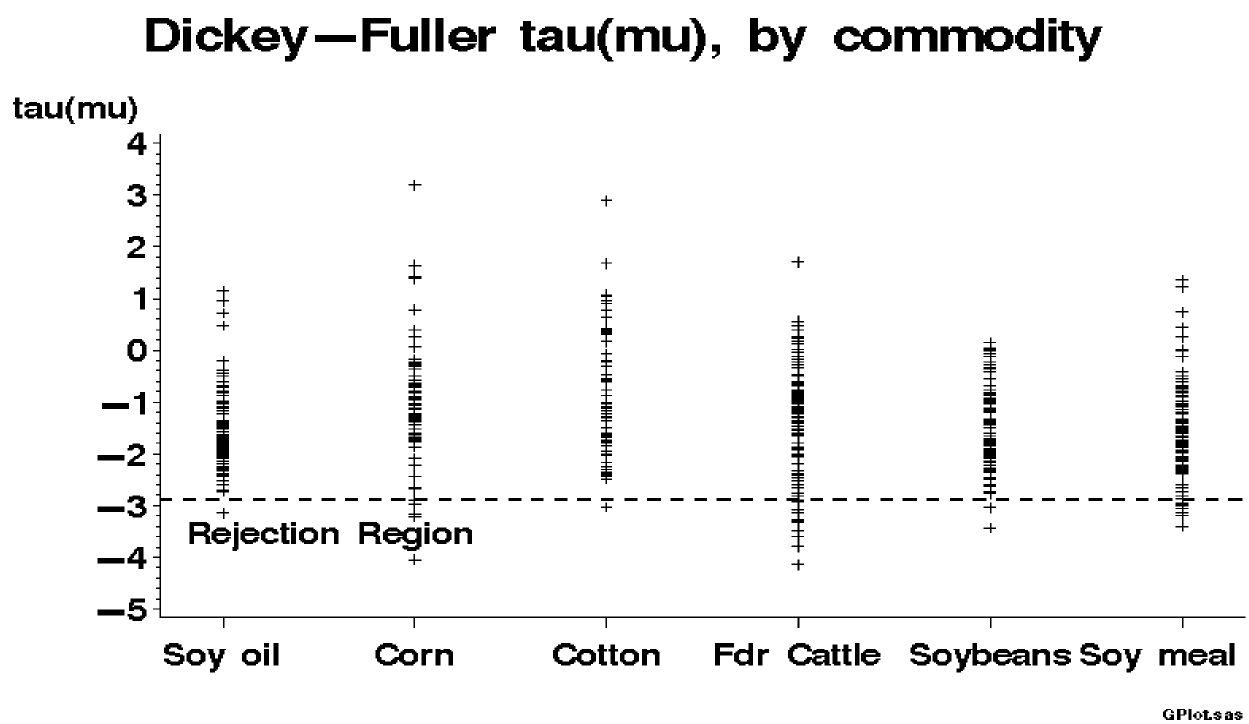

Fig 1a. Tests of H_0: $\gamma_T = 0$

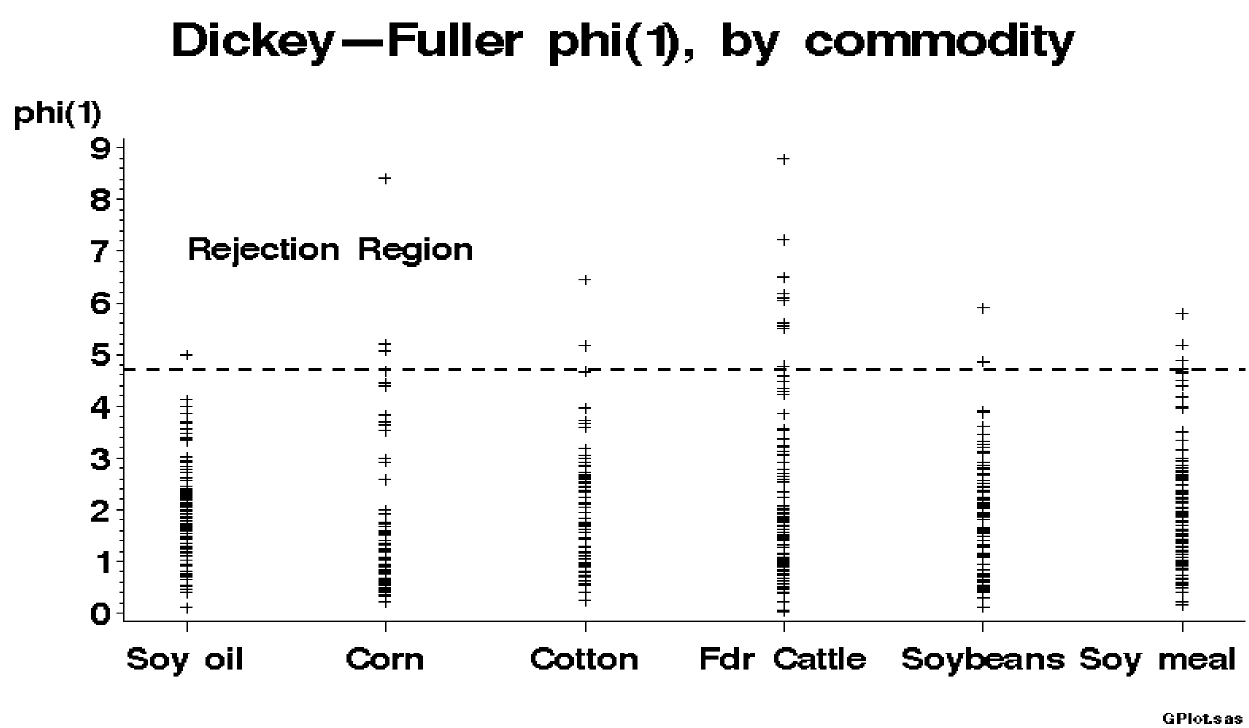

Fig 1b. Tests of H_0: $a_T = \gamma_T = 0$

Figure 1. Dickey Fuller tests of futures prices.

$$(F_{Tt}-S_t) / S_t = \alpha_{1t}(T-t) + \alpha_{2t}(T-t)^2 + \alpha_{3t}(T-t)^3 \quad T \in M_t,\ t = 1, 2, \ldots N_0 \tag{8c}$$

Given the estimated αs from (8c), (8b) is used to estimate μ_{0t} in (4a) by replacing τ with Δt.

Two pertinent empirical questions are. (1) How well does (8c) fit the data for the more than 3,000 trading days and six commodities in the sample? and (2) How well does the resulting model forecast spot price changes? The results in table 4 address these questions. The question about how well the model fits the data is addressed by examining the distribution of the R^2s that result from fitting (8c). The median R^2 ranges from 0.958 to 0.993 (table 4). Examining the first quartile R^2 values also reveals that most of the R^2s are high so we conclude that (8c) fits the data well. However, the model contains 3 parameters estimated from just a few daily futures price quotes. The significance levels associated with testing H_0: $\alpha_{1t} = \alpha_{2t} = \alpha_{3t} = 0$ accounts for the paucity of degrees of freedom. Table 4 indicates that the hypothesis is rejected at the five percent significance level between 62 percent of time (corn) and 97 percent of the time (soy meal). These rejection rates far exceed what would be expected if there was no relationship between futures prices, spot prices, and time to maturity. Hence, the relationship in (8c) is statistically significant.

The forecasting performance of the model is assessed by generating forecasts with

$$[S_{t+\Delta t} - S_t) / S_t]_{Pred} = \hat{\alpha}_{1t}\Delta t + \hat{\alpha}_{2t}\Delta t^2 + \hat{\alpha}_{3t}\Delta t^3 \tag{9a}$$

and then comparing these forecasts to actual realizations with the regression[5]

$$[(S_{t+\Delta t} - S_t) / S_t]_{Actual} = \beta_0 + \beta_1 [(S_{t+\Delta t} - S_t) / S_t]_{Pred} \tag{9b}$$

Table 4 reports the parameter estimates and the estimated standard errors for β_0 and β_1, the regression R^2, the regression F statistic, the probability of a larger F statistic, and tests of forecast unbiasedness corresponding to β_0=0, β_1=1, and β_0=0 and β_1=1. The pertinent features of these results are that (1) even though the regressions have low R^2s, they are significant at beyond the five percent level with the exception of soybean oil, (2) in all cases there is a positive and significant relationship between the forecast value and realization and for four of the six commodities (corn, cotton, soybeans, and soy meal) this relationship is not significantly different from one at the five percent significance level, (3) forming short-term expectations of period-to-period price changes as outline above tends to under predict changes in the price of corn (though not significantly so) and over predict changes in the spot price of the other commodities, and (4) the model gives unbiased forecasts for corn, soybeans and soybean meal, it does very poorly in predicting soy oil prices and is biased in predicting cotton and feeder cattle prices. One explanation of this forecasting performance is that the model is estimated using futures prices to represent spot prices expected to occur as far as one year into the future while the forecast is generated for a period of one to two days into the future. Alternative specifications such as using just the nearby contract were also estimated and according to the statistics corresponding to those

[5] To correct for heteroscedasticity due to unequally spaced observations, both sides of (8c) are divided by $\sqrt{\Delta t}$.

Table 4. Regression results of $(S_{t+\Delta t}-S_t)/S_t = a + b\,(\hat{\alpha}_{1it}\Delta t + \hat{\alpha}_{2it}\Delta t^2 + \hat{\alpha}_{3it}\Delta t^3)$.

Commodity	**Corn**	**Cotton**	**Feeder cattle**	**Soybeans**	**Soy meal**	**Soy oil**
Observations	3,077	3,053	3,077	3,077	3,077	3,077
Measures of fit for $(F_{tT}-S_t)/S_t = \alpha_{1it}(T-t) + \alpha_{2it}(T-t)^2 + \alpha_{3it}(T-t)^3 \quad T \in M$						
R^2						
Minimum	0.126	0.032	0.073	0.104	0.275	0.152
1st quartile	0.930	0.959	0.904	0.946	0.945	0.975
Median	0.982	0.987	0.958	0.987	0.985	0.993
H_0: $\alpha_1=\alpha_2=\alpha_3=0$						
Rejections (5% signif)	1,900	2,143	2,868	2,775	2,992	2,980
Rejection rate	61.6%	70.2%	93.2%	90.2%	97.3%	96.9%
Measures of forecast accuracy for $[(S_{t+\Delta t}-S_t)/S_t = \beta_0 + \beta_1\,(\hat{\alpha}_{1it}\Delta t + \hat{\alpha}_{2it}\Delta t^2 + \hat{\alpha}_{3it}\Delta t^3)](\Delta t)^{0.5}$						
β_0	0.000507	-0.000682	0.00210	-0.000364	0.000316	-0.000111
Std Err	0.000278	0.000338	0.000306	0.000259	0.000268	0.000265
β_1	1.2675	0.6753	0.7731	0.8304	0.8116	0.2809
Std Err	0.2142	0.1742	0.0973	0.2817	0.1893	0.1951
R^2	0.0113	0.0049	0.0204	0.0028	0.0059	0.0007
$F(\beta_0=0, \beta_1=0)$	17.50	7.52	31.97	4.36	9.19	1.05
Prob > F	<.0001	0.0006	<.00001	0.0129	0.0001	0.3509
$F(\beta_0=0)$	3.33	4.08	46.96	1.98	1.39	0.17
Prob > F	0.0681	0.0436	<.0001	0.1599	0.2391	0.6770
$F(\beta_1=1)$	1.56	3.47	5.43	0.36	0.99	13.59
Prob > F	0.2118	0.0624	0.0198	0.5471	0.3197	0.0002
$F(\beta_0=0, \beta_1=1)$	1.93	8.10	104.11	2.25	1.57	8.77
Prob > F	0.1453	0.0003	<.0001	0.1060	0.2083	0.0002

reported in table 4, performed worse than the reported model. In light of these results, we will use the fitted forecast, $\beta_0 + \beta_1 [(S_{t+\Delta t}-S_t)/S_t]_{Pred}$ as our conditional spot price expectation.

Conditional volatilities. Having estimated the conditional means for futures prices (zero) and spot prices, we can now estimate the variances (volatility) represented by the empirical model in (5a) through (5d). In the interest of parsimony we restrict our attention to the ARCH specification of (5c). Table 5 shows the results. They indicate a significant relationship between volatility and time to maturity, and that this relationship consists of significant linear (θ_1) and quadratic (θ_2) components. Estimates of φ_1 measure serial correlation in the volatility. This tends to be insignificant in the futures markets but significant in cash markets. This indicates that futures markets absorb and digest new information quickly and that uncertainty is resolved quickly so that each day's volatility reflects uncertainty at that instant. In contrast cash markets take longer to adjust because physical commodity movements are eventually required for cash market arbitrage. Also, delayed volatility adjustments in the futures markets would imply non-instantaneous adjustment in premiums for options on the futures contracts. This implies inefficiencies in the options markets.

The column headed with (T-t)* in table 5 estimates the time-to-maturity corresponding to volatility extremes. It is estimated from the time-to-maturity parameters as $-\theta_1 / 2\theta_2$. These extreme values range from a minimum of 131 days for March corn to a maximum of 259 days for May feeder cattle. The positive second derivative of the time-to-maturity effect ($\partial^2 h_t/\partial(T-t)^2 = 2\theta_2$) indicates that volatility reaches a minimum at this point. These results agree with maturity effects found by Milonas and Galloway and Kolb though the estimated timing of the minimum is heretofore unreported.

Alternative specifications were estimated to assess the robustness of the results reported in table 5. The results in table 5 use the fitted forecast value generated by (9b) as conditional means.[6] Alternative specifications include using a conditional mean of zero for soybeans because the current model of the soybean oil conditional mean could not explain any variation at usual levels of significance (i.e. H_0: R^2=0 could not be rejected at the five percent level of significance). The conditional mean imputed by (9a) was used for corn, soybeans and soybean meal because the hypothesis that β_0 =0 and β_1 =1 could not be rejected. The estimated results did not change significantly from those reported in table 5 when these alternative conditional means were used.

Other specifications are suggested by the results in table 5. As reported, when the model includes time-to-maturity terms, the autoregressive term is not significant (the futures markets case) and when the model doesn't include time to maturity effects the serial correlation of volatility is significant (the spot market case). When the linear and quadratic time-to-maturity effects are excluded from the futures price model, the serial correlation of futures-price volatility did not become significant. Likewise, excluding the serial correlation of futures-price volatility had little impact on the parameter estimates for θ_{1T} and θ_{2T}, on the estimated time-to-maturity associated with the extreme of volatility, and on the direction of change in volatility as contracts

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6 This is not strictly a conditional mean because the parameters β_0 and β_1 were estimated from the entire sample rather than from the information available at time t.

Table 5. Estimated volatility behavior in spot and futures markets.

Commodity	**θ_0**	**θ_1 (x10^{-2})**	**θ_2 (x10^{-4})**	**φ_1**	**RMSE**	**(T-t)***
Corn (3,014 obs)						
SPOT	1.857****			0.123****	5.286	
	(0.110)			(0.018)		
MAR	1.976***	-2.835***	1.081****	0.003	10.995	131
	(0.578)	(0.747)	(0.201)	(0.018)		
MAY	3.919***	-6.410****	2.183****	-0.001	20.916	147
	(1.129)	(1.449)	(0.388)	(0.018)		
JUL	5.225****	-7.645****	2.427****	0.002	22.492	157
	(1.227)	(1.555)	(0.415)	(0.018)		
SEP	3.457****	-4.013****	1.232****	0.003	13.004	163
	(0.708)	(0.897)	(0.239)	(0.018)		
DEC	2.720***	-3.610***	1.287****	0.004	15.504	140
	(0.843)	(1.082)	(0.290)	(0.018)		
Cotton (2,990 obs)						
SPOT	2.095****			0.029*	6.048	
	(0.114)			(0.018)		
MAR	3.606****	-4.220****	1.324****	0.003	15.899	159
	(0.839)	(1.078)	(0.289)	(0.018)		
MAY	3.277****	-3.711****	1.183****	0.002	11.708	157
	(0.631)	(0.810)	(0.217)	(0.018)		
JUL	4.120****	-5.137****	1.619****	0.005	17.911	159
	(0.990)	(1.254)	(0.333)	(0.018)		
OCT	2.819****	-2.722***	0.786****	0.004	10.760	173
	(0.581)	(0.739)	(0.198)	(0.018)		
DEC	3.313****	-3.873****	1.197****	0.001	13.212	162
	(0.729)	(0.928)	(0.248)	(0.018)		
Feeder cattle (2,363 obs)						
SPOT	0.996****			0.072***	8.434	
	(0.187)			(0.021)		
JAN	0.461****	-0.232**	0.065**	0.028	1.513	179
	(0.085)	(0.108)	(0.029)	(0.020)		
MAR	0.538***	-0.527***	0.183***	0.005	2.635	144
	(0.147)	(0.201)	(0.056)	(0.020)		
APR	0.272****	0.118**	-0.046***	0.111****	0.600	128
	(0.036)	(0.049)	(0.013)	(0.016)		
MAY	0.413****	-0.104	0.020	0.037**	1.043	259
	(0.068)	(0.087)	(0.023)	(0.018)		
AUG	0.418****	-0.135**	0.041**	0.043**	0.967	165
	(0.049)	(0.065)	(0.018)	(0.017)		
SEP	0.494****	-0.256***	0.072***	0.067****	0.872	178
	(0.049)	(0.066)	(0.019)	(0.017)		
OCT	0.605****	-0.420****	0.119****	0.040**	1.091	177
	(0.068)	(0.088)	(0.024)	(0.018)		
NOV	0.551****	-0.392***	0.111***	0.019	1.647	177
	(0.109)	(0.139)	(0.037)	(0.020)		
Soybeans (2,985 obs)						
SPOT	1.284****			0.054****	3.001	
	(0.058)			(0.014)		
JAN	1.514****	-0.866***	0.296****	0.024	4.145	146
	(0.203)	(0.255)	(0.068)	(0.016)		

Table 5. (Continued.) Estimated volatility behavior in spot and futures markets.

Commodity	**θ_0**	**θ_1 (x10^{-2})**	**θ_2 (x10^{-4})**	**φ_1**	**RMSE**	**(T-t)***
Soybeans (Continued)						
MAR	1.664****	-1.329****	0.461****	0.010	4.756	144
	(0.234)	(0.300)	(0.081)	(0.017)		
MAY	2.003****	-2.006***	0.670****	0.002	7.836	150
	(0.416)	(0.533)	(0.143)	(0.018)		
JUL	1.885****	-1.529***	0.504***	-0.002	8.363	152
	(0.437)	(0.554)	(0.148)	(0.017)		
AUG	2.137****	-1.656****	0.492****	0.007	5.375	168
	(0.274)	(0.345)	(0.093)	(0.017)		
SEP	1.631****	-0.575***	0.125***	0.043***	3.022	230
	(0.133)	(0.162)	(0.043)	(0.014)		
NOV	1.523****	-0.576***	0.169***	0.029**	3.340	170
	(0.148)	(0.182)	(0.049)	(0.014)		
Soy meal (2,927 obs)						
SPOT	1.799****			0.108****	4.185	
	(0.087)			(0.016)		
JAN	1.829****	-1.151***	0.413****	0.029*	5.641	139
	(0.296)	(0.375)	(0.100)	(0.017)		
MAR	2.346****	-2.301***	0.784****	0.005	8.807	147
	(0.462)	(0.596)	(0.161)	(0.018)		
MAY	3.061***	-3.708***	1.232***	-0.002	17.078	150
	(0.932)	(1.187)	(0.317)	(0.018)		
JUL	3.283***	-3.993***	1.315***		18.721	152
	(1.014)	(1.293)	(0.346)	(0.018)		
AUG	2.924****	-3.065***	0.965****	0.003	12.813	159
	(0.693)	(0.887)	(0.238)	(0.018)		
SEP	2.952****	-3.220***	1.039****	0.002	13.595	155
	(0.742)	(0.944)	(0.252)	(0.018)		
OCT	1.948****	-0.889**	0.235**	0.027	5.251	189
	(0.273)	(0.346)	(0.093)	(0.017)		
DEC	1.687****	-0.575	0.191**	0.032*	5.284	150
	(0.276)	(0.352)	(0.095)	(0.017)		
Soy oil (2,977 obs)						
SPOT	1.599****			0.120****	3.486	
	(0.073)			(0.014)		
JAN	1.958****	-1.489***	0.506****	0.012	6.903	147
	(0.367)	(0.464)	(0.123)	(0.017)		
MAR	1.943****	-1.629****	0.562****	0.018	5.576	145
	(0.283)	(0.363)	(0.098)	(0.017)		
MAY	1.878****	-1.498****	0.508****	0.004	4.698	147
	(0.235)	(0.299)	(0.080)	(0.017)		
JUL	2.209****	-1.862****	0.587****	0.015	5.538	158
	(0.284)	(0.359)	(0.096)	(0.017)		
AUG	2.205****	-1.699****	0.506****	0.016	5.688	168
	(0.296)	(0.375)	(0.101)	(0.017)		
SEP	2.010****	-1.185****	0.321****	0.036**	3.722	184
	(0.185)	(0.230)	(0.061)	(0.016)		
OCT	1.975****	-1.285****	0.382****	0.024	4.341	168
	(0.219)	(0.275)	(0.073)	(0.016)		
DEC	2.200****	-1.784***	0.581****	0.013	7.517	154
	(0.397)	(0.507)	(0.136)	(0.017)		

approach maturity. Thus, the results shown in table 5 appear to be robust with respect to model specification.

Conditional Correlation. Table 6 shows the results of fitting (6). These results indicate a number of consistencies as well as a number of issues that needing further attention. First, the number of observations for corn drops from 3,014 in table 5 to 1,607 in table 6. This results from the fitted values of h_{Tt} being negative for numerous contracts and at certain times of the year. Because the square root of a negative number is undefined, (6) could not be fit for many of the observations. The parameter estimates for corn are thus of limited value. This was not a problem however for the other commodities and a great deal of consistency appears in the results. For cotton, soybeans and soy meal, the linear time-to-maturity parameter is positive when significant while the quadratic time-to-maturity parameter is negative when significant. This indicates that the spot-futures price correlation increases as time to maturity decreases (i.e. the spot-futures price correlation increases as the contract approaches maturity). Also, the coefficient on last period's correlation coefficient is typically positive and significant. The time to maturity when the correlation seems to achieve its minimum is relatively stable so long as both λ_1 and λ_2 are both significant, ranging from 92 days for December soy meal to 151 days for January soybeans. The estimated coefficients for feeder cattle infrequently display significance most likely because of the nonstorability of feeder cattle.

Implications and Conclusions

This study seeks to determine the behavior of hedging effectiveness associated with using imminently maturing futures contracts. Our analysis indicates that the maturity effect applies for each of the contracts examined, as each contract's volatility increases from its minimum at five to six months before maturity. While the maturity effect is significant, the effectiveness of hedging also depends on the covariance between cash and futures price changes. Our results indicate that the volatility increase associated with the maturity effect outweighs whatever the movements occur in the covariance between cash and futures price changes so that the correlation between cash and futures prices declines as the contract approaches maturity. Hence, hedging with imminently maturing futures contracts is less effective than hedging with more distantly maturing contracts in accordance with common practice. However, more analysis is needed.

Specifically, the volatility of the spot was autoregressive heteroscedastic without seasonal effects. The addition of seasonal effects to the spot price volatility model might displace the apparent autoregressive heteroscedasticity of this series. Second, the representation of futures price volatility as a function of time-to-maturity might be improved with a functional form that is more flexible than the quadratic specification. The quadratic form imposes symmetry about its minimum. Such a specification might restrict the true behavior of volatility. Third, the estimation of hedging effectiveness requires estimation of the correlation between cash and futures price changes. This estimation should be done in a more complete specification such as a multivariate GARCH specification similar to the approach used by , Moschini and Meyers (2002), and Haigh and Holt (2002)to estimate variable hedge ratios. Finally, once these estimation issues have been addressed, optimal contract selection rules can be devised based on the hedging effectiveness of the imminently maturing contract relative to the hedging effectiveness of the more distant contract.

Table 6. Estimated spot-futures price correlation behavior.

Commodity	λ_0	λ_1 (x10^{-2})	λ_2 (x10^{-4})	λ_3	RMSE	(T-t)*
Corn (1,607 obs)						
MAR	0.223	-0.057	0.004	0.117****	3.003	693
	(0.216)	(0.166)	(0.032)	(0.012)		
MAY	0.226****	-0.061	0.001	0.118****	3.014	4180
	(0.039)	(0.048)	(0.013)	(0.013)		
JUL	0.206***	-0.147	0.032	0.055***	4.090	227
	(0.063)	(0.129)	(0.036)	(0.017)		
SEP	0.079*	0.349***	-0.113****	0.124****	3.276	154
	(0.044)	(0.109)	(0.029)	(0.014)		
DEC	-0.349***	0.818****	-0.259****	0.117****	3.182	158
	(0.098)	(0.185)	(0.061)	(0.012)		
Cotton (2,990 obs)						
MAR	0.346****	0.228***	-0.105****	0.066****	3.261	109
	(0.045)	(0.072)	(0.020)	(0.011)		
MAY	0.325****	0.218***	-0.092****	0.074****	3.099	119
	(0.040)	(0.059)	(0.016)	(0.010)		
JUL	0.236****	0.246***	-0.082****	0.080****	3.100	150
	(0.040)	(0.064)	(0.017)	(0.011)		
OCT	0.369****	-0.068	0.003	0.067****	2.795	1197
	(0.039)	(0.060)	(0.016)	(0.011)		
DEC	0.412****	0.039	-0.047***	0.077****	2.618	41
	(0.032)	(0.052)	(0.014)	(0.010)		
Feeder cattle (2,363 obs)						
JAN	0.044*	-0.003	-0.005	0.003	0.438	-32
	(0.025)	(0.031)	(0.008)	(0.012)		
MAR	0.037	-0.091*	0.033**	0.010	0.559	137
	(0.039)	(0.053)	(0.014)	(0.016)		
APR	0.086***	-0.063	0.013	-0.011	0.478	242
	(0.033)	(0.042)	(0.012)	(0.011)		
MAY	0.097***	-0.057	0.009	-0.017	0.538	321
	(0.032)	(0.039)	(0.011)	(0.011)		
AUG	-0.009	0.058**	-0.015**	-0.007	0.505	187
	(0.022)	(0.024)	(0.007)	(0.009)		
SEP	0.001	0.026	-0.006	-0.007	0.506	225
	(0.024)	(0.029)	(0.008)	(0.010)		
OCT	0.022	-0.025	0.011	-0.005	0.481	115
	(0.023)	(0.029)	(0.008)	(0.010)		
NOV	-0.024	0.067**	-0.018**	-0.007	0.437	185
	(0.024)	(0.031)	(0.008)	(0.011)		
Soybeans (2,985 obs)						
JAN	0.568****	0.348****	-0.115****	0.046****	2.473	151
	(0.040)	(0.041)	(0.011)	(0.008)		
MAR	0.581****	0.356****	-0.119****	0.041****	2.424	150
	(0.037)	(0.038)	(0.010)	(0.008)		

Table 6. (Continued.) Estimated spot-futures price correlation behavior.

Commodity	λ_0	λ_1 (x10^{-2})	λ_2 (x10^{-4})	λ_3	RMSE	(T-t)*
Soybeans (Continued)						
MAY	0.599****	0.432****	-0.150****	0.036****	2.382	145
	(0.037)	(0.042)	(0.011)	(0.008)		
JUL	0.637****	0.332****	-0.121****	0.034***	2.815	137
	(0.062)	(0.073)	(0.019)	(0.010)		
AUG	0.667****	0.234****	-0.087****	0.049****	2.606	134
	(0.042)	(0.046)	(0.013)	(0.008)		
SEP	0.690****	0.149***	-0.064****	0.051****	2.495	116
	(0.041)	(0.039)	(0.010)	(0.008)		
NOV	0.661****	0.206****	-0.080****	0.032****	2.553	128
	(0.039)	(0.037)	(0.010)	(0.008)		
Soy meal (2,927 obs)						
JAN	0.419****	0.332****	-0.123****	0.038****	3.113	135
	(0.048)	(0.054)	(0.014)	(0.009)		
MAR	0.369****	0.393****	-0.134****	0.040****	3.043	147
	(0.040)	(0.051)	(0.014)	(0.009)		
MAY	0.399****	0.359****	-0.121****	0.030***	3.169	148
	(0.050)	(0.072)	(0.020)	(0.011)		
JUL	0.537****	0.130	-0.065***	0.039***	3.545	101
	(0.057)	(0.082)	(0.022)	(0.011)		
AUG	0.566****	0.153***	-0.078****	0.044****	2.945	98
	(0.038)	(0.052)	(0.014)	(0.009)		
SEP	0.550****	0.155**	-0.078****	0.043****	3.121	100
	(0.047)	(0.064)	(0.017)	(0.010)		
OCT	0.571****	0.052	-0.050****	0.048****	2.989	51
	(0.037)	(0.037)	(0.010)	(0.008)		
DEC	0.552****	0.127***	-0.069****	0.041****	3.054	92
	(0.039)	(0.039)	(0.010)	(0.008)		
Soy oil (2,977 obs)						
JAN	0.622****	0.283****	-0.104****	0.035****	2.738	136
	(0.036)	(0.037)	(0.010)	(0.008)		
MAR	0.654****	0.243****	-0.093****	0.030***	2.740	130
	(0.041)	(0.047)	(0.013)	(0.009)		
MAY	0.664****	0.259****	-0.100****	0.027***	2.714	129
	(0.039)	(0.040)	(0.011)	(0.008)		
JUL	0.600****	0.352****	-0.125****	0.032***	2.882	141
	(0.042)	(0.050)	(0.014)	(0.008)		
AUG	0.606****	0.296****	-0.104****	0.039****	2.717	143
	(0.032)	(0.036)	(0.010)	(0.007)		
SEP	0.604****	0.274****	-0.097****	0.033****	2.659	141
	(0.032)	(0.033)	(0.009)	(0.007)		
OCT	0.580****	0.349****	-0.125****	0.028***	2.691	140
	(0.035)	(0.036)	(0.010)	(0.007)		
DEC	0.559****	0.426****	-0.150****	0.035****	2.900	142
	(0.043)	(0.051)	(0.014)	(0.009)		

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