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Theoretical and Empirical Considerations

by

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This study analyzes the time series statistical properties of wheat futures prices to determine whether price behavior differs among intramarket contracts. We argue that the differential role of inventories, information, hedging objectives and probability of stockout across seasons provide a theoretical basis and empirical interest for finding such a difference. The behavior of May and September futures prices are indeed found to be significantly different and in ways consistent with theory. Furthermore, an endogenous contract arrival effect is found for both contracts, demonstrating the importance of developing models which incorporate market activity proxies.

Introduction

Current theoretical methods of commodity price determination emphasize the importance of storage in transmitting price shocks across periods. Nonetheless, these models do not completely explain the actual behavior of prices (Deaton and Laroque, 1992; Blank, 1989). Because storage and shocks have significantly different roles in price determination over the year, one might expect variations in price behavior among month-specific contracts. That is the focus of this study. In short, this paper conceptualizes intramarket differences implied by theoretical models of commodity price behavior, empirically tests the hypotheses raised by such analysis, and compares and contrast the findings to technical trading schemes to address these objectives. We focus on the behavior of wheat futures prices, using five years' daily data.

The paper is divided into four sections. First, we briefly review the literature on storage, commodity prices and futures price behavior. Second, comes a conceptual model of why differential price behavior is expected among intramarket contracts. Then we present methodology and empirical results of the price analysis conducted on September and May wheat futures price series. Finally, we briefly compare these results to charting methods developed by technical analysts. This paper also serves as a starting point for conceptualizing potential time series econometric issues related to modeling futures prices in a manner consistent with the underlying theory of storable commodities. However, the main purpose of this paper is to empirically analyze how commodity prices vary among seasonal contracts (referred to as intramarket contracts from this point forward in the paper).

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Futures Price Behavior

Price analysis has been an essential component of futures markets research. The literature reveals two important findings about futures price series. First, the unconditional distribution of most futures returns is leptokurtic (Hall, Brorsen, and Irwin, 1989), i.e., exhibits fatter tails than would be found in a normal distribution. This reflects a higher probability of extremely high or low returns. Second, most futures returns are conditionally heteroskedastic (Fujihara and Park, 1990; Yang and Brorsen, 1995), implying that current price variability can be explained by past information. Given the nature of commodity markets, these statistical properties may be explained theoretically, as has been the case with cash prices.

Although it has been shown that cash prices are affected by storage, it is not certain that the same effects would be found in futures price series. Research on the effects of storage on futures prices has been limited in scope. Empirical tests of the "accuracy" of futures markets' response to information (including stock volumes) have sought to identify bias in the pricing process, mostly focusing on an analysis of backwardation[1]. Three traditional explanations for the backwardation present in futures prices have developed in the futures literature: that the future is discounted relative to the present (Vance, 1946); convenience yield (Kaldor, 1939); and finally, that futures prices are downward biased by the risk premia afforded agents who are allowed to lock in prices.

The convenience yield hypothesis is based on the concept that agents have an incentive to store inventories locally when aggregate stocks are low. The convenience yield hypothesis pertains to any stored good regardless of the frequency of its production. As Frechette summarizes, "at one extreme, an agricultural commodity may be harvested annually and stored through the year; at the other extreme, a metal may be continuously mined and refined." The expected differences in intramarket price behavior is the motivation for the analysis of September and May contracts in this study. However, it will be argued here that differential price behavior among these contracts is not related to convenience yield, but rather, structural factors.

Williams and Wright (1991) posit another theory to explain the relationship between cash and futures price behavior based on the probability of stockout and nonnegativity constraints on stocks. If future spot prices are expected to increase, locking into a futures price is not as attractive an option for hedgers or speculators. Thus, futures prices are downward biased. However, this would only happen in certain market conditions since high current levels of stocks may signal that future spot prices will not be significantly increasing. This theory lends support to the hypothesis of differential impacts of storage across

[1] Normal backwardation was initially described by Keynes (1921) as a situation in which spot prices are higher than forward prices for a commodity. It is now more frequently used to describe systematic downward biased estimates of an expected spot price over time.

intramarket contracts since the probability of stockout varies across the year, especially in crops such as wheat which are dominated by one annual harvest.

Technical trading is based on the belief and ability of analysts to find and exploit patterns and formations in price series that allow them to profit from such analysis. However, these practitioners take a very different approach than do academic economists to understanding price behavior, concentrating on some market fundamentals, as well as market perceptions, or the psychology of trading (CTS, 1996). As would be expected, many of the traditional formations found in technical charting analysis are consistent with the expected statistical properties of commodity futures prices. This offers an interesting comparative analysis for this study, one which we briefly explore in the penultimate section.

The Role of Storage in Price Determination

Inventories were first incorporated into models of spot and futures price behavior by Williams (1935). He demonstrated that expected prices should follow an upward-climbing path whenever stocks are held using the Hotelling rule (1931). It follows that futures prices are rational expectations of future spot prices in a risk neutral market. Yet, the actual behavior of prices seem more complex.

The role of storage in price determination has primarily been addressed from a empirical perspective (Stein, 1961), including studies analyzing the convenience yield and any effects that inventories may have on expected price levels. The seasonal nature of inventory levels on futures markets, called the inventory effect, provides a benchmark for the theoretical argument made in this study about varying price behavior among intramarket contracts. Lien (1987) found no conclusive results for the "inventory effect" in corn or wheat futures markets, lending support to the hypothesis of year-round, efficient markets. He tested this inventory hypothesis by analyzing whether seasonal changes in inventory levels create potential for profitable price changes, i.e., $E(P_{t+1}) \neq P_t$. However, the higher-order statistical properties of futures prices as they relate to inventory levels have not been analyzed and may better explain how storage affects intramarket commodity price behavior. These factors are the focus of this study.

Working (1949) made the first attempt to explain commodity prices in terms of a simple theory based on storage. He focused attention on the role that storage plays in transferring commodities from relatively plentiful times to relatively scarce times, and how this affects price behavior. More recently, Deaton and Laroque noted that theory of the determination of commodity prices, although well-developed, cannot explain the actual behavior of prices. Their theory of price behavior, like Williams and Wright's, follows a traditional supply and demand approach with explicit attention to the role of inventories on speculative agents' expectations. They found that a standard rational expectations competitive storage model of commodity prices can explain a number of the data's statistical properties, including skewness, and the existence of rare but violent explosions in prices, coupled with a high degree of price autocorrelation in more stable periods. Their approach is the theoretical basis for this study.

In short, Deaton and Laroque analyzed prices as a function of potential stock-outs. The nonnegativity constraint inherent to grains storage implies asymmetry in storable commodities' price distributions. In effect, this introduces a non-linearity to the system which can be thought of as establishing a threshold price as a lower bound for futures prices, but no similar upper bound constraining prices. Thus, one would expect positive skewness and higher variance in prices as prices increase. Conversely, with no potential for negative inventories, conditional variance and skewness should fall with prices. Thus, the variance and skewness of next period's price distribution are non-decreasing functions of current price. In general, prices spend long periods at low, stable levels, showing little movement but high autocorrelation from year to year. Once a high price emerges, precipitating a high probability of further high prices due to autocorrelation, the probability of stockout rises, resulting in the peaks found in commodity price series.

Storage permits the intertemporal transmission of shocks to conditional price distributions. Where stocks are always positive, there should thus be considerable price autocorrelation and persistence of shocks, and autoregressive conditional heteroskedasticity (ARCH). However, there should not be discernable conditional skewness in series so long as ample stocks remain on hand. However, when stocks dwindle, i.e., stock-outs occur, ARCH effects should diminish and positive price spikes (i.e., skewness) should appear.

The Deaton and Laroque and Williams and Wright models are based on the idea that the probability of stock-outs, $Pr_1(\text{Stock-out}_{t+1} \mid \Phi_t)$, is directly related to current inventories on hand and the current level of prices ($P_t, I_t \in \Phi_t$). First, the basic effect of storage on price behavior is defined as,

(1) $$\frac{\partial\, Pr\ (Stock\text{-}out_{t+1} | F_t)}{\partial\, I_t(P_t)} < 0$$

where I_t, inventories at time t, is itself a function of current prices. In particular,

(2) $$\frac{\partial\, I_t}{\partial\, P_t} < 0$$

if speculative storers maximize profits. This implies that,

(3) $$\frac{\partial\, Pr\ (Stock\text{-}out_{t+1})}{\partial\, (P_t)} > 0$$

Because storage permits intertemporal trade, it increases the price elasticity of supply. Stock-outs reduce storage by definition, thereby dampening supply elasticity and leading to greater price variability in the face of demand shocks. Given the relationship between current prices and the probability of future stock-out, these effects yield asymmetric price shocks. Mathematically, we posit that

(4) $$\frac{\partial\, \sigma^i_{t+1}}{\partial\, Pr(Stock\text{-}out_{t+1})} > 0 \text{ for } i=2,3,4$$

where σ^i is the i^{th} central moment of the price distribution. Recognizing the relationship in (3), this suggests that

$$\frac{\partial \sigma^i_{t+1}}{\partial P_t} > 0 \quad \text{for } i=2,3,4. \tag{5}$$

The conceptual basis for this study is the hypothesis that futures prices will be similarly affected by the probability of a stockout, and thus the level of storage of a commodity and its current price. However, information on, and perceptions of stock levels vary throughout the year, prompting our interest in empirical analysis of intramarket contracts.

Intramarket Contract Analysis

The role storage plays in price determination may vary over time whenever commodity supply depends on a periodic harvest, annually in the case of wheat. Thus, a spring wheat contract may exhibit different price behavior than a fall wheat contract. If storage were plentiful, and the demand for futures contracts was reasonably uniform throughout the year, one would expect quite similar price patterns in spring and fall futures contracts. But, when market supply is dominated by an annual harvest, such as is the case with wheat, and competitive storage does not always ensure sufficient positive inventories, there may be important intramarket pricing differences.

Moreover, demand for futures contracts plays a role. Thus, we test for an endogenous contract arrival effect, which measures whether relatively early market activity on the coming year's futures contract (a proxy for demand of futures contracts) affects price levels. To test for such an effect, a structural variable (TRUN) was added into the econometric model, where TRUN was the number of days remaining in the maturing contract when the next year's contract became active. The opposite method of truncation, truncating the new contract prices until the current contract matured, yielded qualitatively similar time series results with the exception of insignificant TRUN variables. However, the former method was eventually used because we argue that a relatively earlier truncation would allow us to more fully capture the interyear effects of both price behavior and the contract arrival effect[2].

The September and May contracts may have different price behavior for several reasons: the varying role of informational shocks, storage levels and trading volumes throughout the year. Understanding intramarket differences has practical importance as well. For one, producers hedging with the futures market to mitigate price risk will tend to use one specific contract delivery month, depending on their marketing strategy. These agents need information on the price behavior of particular contracts, not the synthetic nearby contract price series commonly studied by academics. Similar arguments could be made for elevators

[2]For example, we expect that the next year's contract will be traded earlier if the maturing year's contract exhibits relatively higher prices. Thus, this method allows us to test if, and to what degree, current price behavior affects the demand for the coming year's futures contract. Moreover, potential for temporal arbitrage should assure similar behavior between the maturing and following year's price behavior.

which hedge their expected supplies, livestock producers who hedge feed supplies, and processors who hedge input supply commodities at particular times of the year.

Another economic factor which varies across time is inventory levels, and thus the transactions costs of using the cash vs. futures market to determine prices. The primary seasonal effect evident with commodities is the 'lumpiness' of the production process. In the case of many commodities, including wheat, the vast majority of supply is based on a once-a-year harvest. Regardless of the average grain stocks for a year, there will always be higher inventory levels immediately following harvest than 6 months later. Thus, prices on futures contracts with different maturity or delivery dates are affected by very different perceptions about the probability of a stockout. As conceptualized above, the probability of a stockout will be influenced by the absolute level of prices, but also by potential replenishment of stocks, in this case, the next annual harvest. The same argument would hold true with respect to the relationship between variability of prices and potential stockouts. Thus, because the underlying wheat inventories are markedly different in these months so should one expect the conditional futures price distributions to differ between May and September contracts. In particular, because September inventories are always considerable, we will expect a near-zero probability of stock-out and thus, GARCH effects without positive residual skewness. In May, however, the opposite is true of inventories, and one would expect residual skewness without GARCH effects.

Williams (1987) concluded that backwardation exhibited in futures markets is because they are used as a instrument to determine approximate cash prices in order to lessen the transaction costs inherent in the cash market. It could be argued that the value of this function fluctuates based not only on market conditions, but also by the time of the year. The cash market transactions costs for a producer selling a commodity already in storage is arguably less than for a producer trying to market a crop which is still not available for delivery. This concept further supports our hypothesis about differential intramarket futures market behavior.

Finally, pertinent information availability varies predictably over the course of the trading year, which influences perceptions of the probability of stockout as well. This lends further support to the idea of intramarket differentials in price behavior. In general, a spring wheat contract (especially the last half of the contract period) trades on known supply since only inventoried stocks are available for consumption prior to the next harvest. The fall wheat contract, in contrast, is more directly affected by information about the incoming supply levels (as determined by periodic crop reports). In short, information on the quantity of replenishment stocks will vary greatly throughout the year as the planting, growing and harvest seasons progress

Empirical Analysis

We study Chicago Board of Trade data on soft red winter wheat futures contract prices determined at the closing of each trading day. Both the May and September future contract prices in our analysis run from January, 1990, to October, 1995. Casual visual analysis of these price series (Figures 1 and 2) reveals standard patterns: significant autocorrelation and long periods of fairly stable prices punctuated by occasional positive spikes and extraordinary volatility in prices.

Table 1. Descriptive Statistics

	Autocorrelation (days)				Coeff. of	Persistence			Relative	Relative
	1	2	3	4	variation	90 days	120 days	180 days	Skewness	Kurtosis
May	0.992	0.984	0.977	0.971	0.100	0.0028	0.0028	0.0030	-0.174	2.942
Sept	0.993	0.987	0.981	0.974	0.114	0.0125	0.0135	0.0055	1.200	5.041

Note: Persistence is the normalized spectral density at zero. The relative skewness measure is $\mu_3/(\mu_2)^{1.5}$, and the relative kurtosis measure is $\mu_4/(\mu_2)^2$, where μ_i is the i^{th} central moment.

The descriptive statistics in Table 1 reveal several of the price characteristics predicted by the conceptual model. Both the May and September contract prices exhibit substantial autocorrelation between daily prices. The coefficients of variation show the two price series are not especially volatile. The persistence, a measure of how long exogenous shock will persist into the indefinite future, is relatively low for both contracts, indicating that shocks' effects dissipate in the medium-term. Finally, the last two columns present the relative skewness and kurtosis of the unconditional price distributions, which one generally compares to the standard normal distribution values of 0 and 3, respectively. The September contract has positive skewness and substantial kurtosis, with tails much fatter than those of the normal distribution, however neither of these conditions are found in the May contract. The findings are basically consistent with others' studies, like Deaton and Laroque.

Time series can be modeled with an Autoregressive Integrated Moving Average (ARIMA) specification to control for the high levels of autocorrelation and potential nonstationarity inherent in high frequency time series data. First, we tested for stationarity in the data series using the Augmented Dickey-Fuller (ADF) unit root test. The ADF t statistics of -1.85 and 0.13 for the original May and September logs of prices, respectively, supported the rejection of a unit root in those series at the 1% significance level. The ADF t-statistics for the first-differences in the logs of May and September prices were -17.49 and -16.69. Thus, both the May and September price series were found to be integrated of order one in their logarithms. Further analysis is thus based on the first differenced log series (Δ ln P).

The next step involved identifying the time series dimensionality of the stationary Δ ln P series. We used Akaike's (1981) information criterion (AIC). In both May and September contracts we found lags of up to five days in both the dependent variable and the residuals were significant, so we estimated an ARIMA (5,5) model. We used the Ljung-Box-Pierce portmanteau Q-statistic to confirm that the residuals from this ARIMA specification follow a white noise process.

Given the volatility clustering apparent in the plotted prices, we next tested for GARCH effects using the Q-statistic on the squared residuals. GARCH processes admit volatility clustering and thus some leptokurtosis to financial futures price series (Bollerslev, 1986), and appear useful to commodity futures price analysis as well (Myers, 1994). Where we found

GARCH effects, we identified the time series dimensionality of the conditional variance following Bollerslev (1988). We then verified these GARCH specifications by a Q-test of the squared normalized residuals, ν_t. We thus model the data generating process of wheat futures price as

(6) $$\Delta \ln p_t = x_t\phi + e_t$$

(7) $$e_t = \nu_t \sqrt{h_t} \text{ where } \nu_t \sim N(0, 1) \text{ and,}$$

(8) $$h_t = \alpha_0 + \sum_{i=1}^{q} \beta i e_t \sum_{i=1}^{p} \alpha_{ih_{t-1}} + \gamma z_t$$

where x_t is a vector of predetermined variables which may include lagged dependent variables and lagged residuals, ϕ is the corresponding vector of parameters. e_t is the disturbance term, which follows a normal distribution with mean zero and conditional variance h_t. The z_t variable permits the inclusion of structural explanatory variables in the conditional variance equation (8).

Finally, x_t and z_t include a structural variable, TRUN, representing the endogenous contract arrival effect. To properly join several years of contract data together, there needed to be a point each year where the data set rolled over from the maturing year's to the next year's contract. Thus, the number of truncated days was included as a regressor on the day when the rollover occurred; TRUN takes the value of zero all other days. Not only does this control for the time series shock of the truncation, but it determines whether there is a predictable effect on the price behavior for these contracts as they roll over from one year to the next. In particular, this tests for market demand, since the number of days truncated indicates how early a critical mass of demand emerged for the new contract. We label this an endogenous contract arrival effect. One possible shortcoming of the test for endogenous contract arrival effects relates to the degrees of freedom available for each contract. With only five years of data, only four "rollover" days exist. However, there is an interesting qualitative point to be made from the variability in truncated days. The May contract's truncation period was relatively consistent with 44, 39, 41 and 40 days, respectively, whereas the September contract's truncation periods were 34, 125, 41 and 15 days, respectively. This intramarket variability in the temporal onset of market activity reinforces our intuition of significant intramarket behavioral differences.

Empirical Findings

Table 2 presents our findings[3]. For the May contract, all of the conditional mean equation variables-the ARMA (5,5) coefficients as well as that on the truncation variable, were significant. The significant and positive TRUN variable indicates that the percent change in prices will increase with the number of days truncated from the maturing contract. At the mean value of 41 days truncated, this represents only a 0.2% stimulus to prices, which persists due to nonstationarity in the price levels. The Box-Pierce Q statistics for the e_t^2

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[3]The model was estimated using Shazam 7.0.

indicate there are no GARCH effects present in the May contract (although significant heteroskedasticity does exist). Moreover, significant positive skewness remains in the residuals. These are precisely the characteristics one would predict for a contract subject to real risk of inventory depletion.

The same ARMA model was estimated for the first differenced log prices on the September contract (Table 3). In contrast to May contract prices, the autocorrelation in September contracts comes with several days' lag. Moreover, GARCH effects are evident in the September series but there is no positive skewness in the (ν_t) residuals. Indeed, skewness is negative and statistically significantly different from zero. The coefficient on the TRUN variable in the conditional mean equation was again positive and significant. At the mean truncation value of 54 days this represents a 1.5% increase in in mean price, nearly an order of magnitude greater than the endogenous contract arrival effects on March prices. These findings are consistent with our interpretation of early contract arrival representing a demand-side effect. Interestingly, this variable has no significant effect on conditional variance.

As expected, there are significant differences in price behavior among the two contracts. The May contract exhibits the positively skewed residuals one expects when there is a positive probability of stock-out. The September contract does not. Instead, it exhibits GARCH effects associated with the intertemporal transmission of price volatility due to storage. March contracts have no GARCH effects. Both model's errors remain heteroskedastic and nonnormal[4], a finding that motivates future research to explore the structural determinants of the higher-order moments of these price series, including capturing asymmetry. Substantial research has been conducted on how to correct for leptokurtosis, but surprisingly little published work has attended to econometric estimation of the positive skewness. This is especially relevant for agriculture, as skewness is to be expected in the prices of storable commodities subject to stock-out.

The endogenous contract arrival effect was a significant explanatory variable in both intramarket contract price series. This clearly needs further analysis since the degrees freedom on this variable were limited in this study. The empirical findings suggest the value of including market activity proxies, and more generally, structural variables to commodity price analysis.

Implications for Technical Trading Analysis

The literature on futures markets has been somewhat dichotomous. Academic researchers have focused on futures market behavior as it relates to efficient markets theory. Meanwhile,

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[4]Dorfman (1993) finds that a large proportion of residuals from agricultural econometric studies are nonnormally distributed. This clearly casts a shadow over maximum likelihood parameter estimates. But until methods based on more general distributions which permit both kurtosis and skewness (i.e., more flexible than student-t distribution) gain currency, the assumption of normality remains the default.

industry researchers have focused on technical analysis and on formulating methods for short-term financial gains from futures markets. Since technical methods rarely have a theoretical justification, and in fact contradict the efficient market hypothesis, they have been virtually ignored by academic researchers. Yet, Blank (1989) points out that technical systems are widespread in the trade literature and have value to industry analysts. The commonly found statistical properties in commodity price series may be captured and exploited by technical trading systems. Positive skewness in futures prices may also indicate that information releases and inventory timing lead to asymmetric price responses. For example, the common belief among industry and academic futures researchers that, *What goes up, comes down faster*, implicitly describes the positive skewness modeled by Deaton and Laroque and Williams and Wright. Academic and industry researchers would most likely gain from further exploring the common basis of their research.

The basis of most technical trading schemes is that trends persist. This concept is inherent to time series forecasting, which relies on the autocorrelation of prices as the primary explanatory variable of current prices. However, technical trading analysts are most interested in the reversal or correction movements of prices, and their strategies focus on correctly predicting when such market actions will occur. Although it is not defined as such, GARCH processes are the basis for most trading strategies which search for breakouts or reversals depending on the variability of price actions.

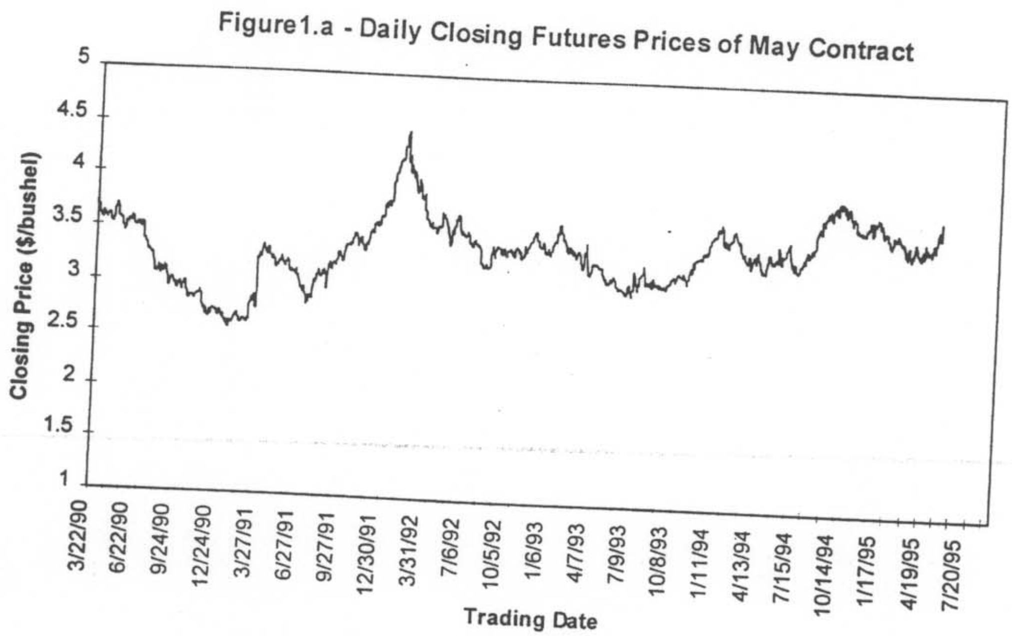
Technical traders understand the importance of not only time series analysis, but structural variables, in charting futures prices (CTS, 1996), and have developed increasingly complex charting methods to exploit information contained in such variables (Levine, 1995). Recently, academic researchers have taken this as a signal in their research. Lamoureux and Lastrapes investigated the role of volume as a structural variable in time series analysis for stock return data to demonstrate that it may explain much of the price behavior captured by ARCH analysis. Yang and Brorsen (1995) likewise integrate structural and time series regressors. This will be the next step in this research project on intramarket contract analysis.

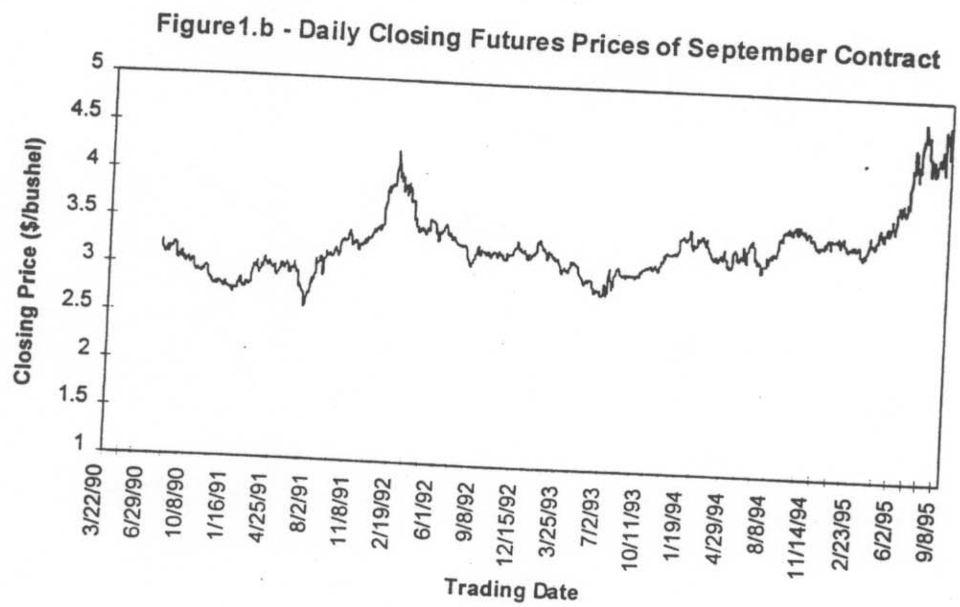
Conclusion

We set out to study the price behavior of two different soft red winter wheat futures contracts (May and September), based on the hypothesis that structural differences in information and storage patterns should cause differences in intramarket contract price behavior. These two price series exhibit many of the same characteristics of long-run commodity price series reported by Deaton and Laroque (1992). There is a high degree of autocorrelation in the price series, just as would be expected in a market where commodity stocks temporally equilibrate interharvest supply and demand conditions. Yet, there are significant differences between the two contracts. The May contract exhibits significant positive skewness but no GARCH effects, while the September contract has GARCH effects without positive residual skewness. Although these empirical findings provide insight into the differences between intramarket contracts, primarily they highlight the need for further econometric innovation in modeling futures prices. One interesting result from this analysis was the significance of the endogenous contract arrival effect, which measures how early the market for a new contract emerges. The timing of market activity significantly affects price levels, although by only modest amounts and with significant differences among intramarket contracts. This effect should be of interest to industry analysts concerned about the rollover effects within contracts.

Understanding the statistical behavior of futures market prices is crucial to the development of hedging and futures market policy research. However, it is not always clear that industry and academic researchers are going in the same direction (Blank, 1989). Further innovation in the theoretical and empirical modeling of futures prices may go a long way toward bridging the gap between scholarly and business inquiry. Thus, it seems essential for academic researchers to understand more of the trade literature as it could signal other price behaviors which may advance our theoretical and empirical understanding of commodity price behavior.

May and September Wheat Futures Prices, Actual[1]





[1] The remaining days of the maturing contract were truncated on the trading day when the next year's contract became active.

Table 2. ARIMA(5,1,5) results for May Contract

Dependent Var. : $\Delta \ln P$	May	
	Coefficient	t-statistic
Constant	-1.75E-05	-0.0611
TRUN	4.33E-04	3.1115*
AR(1)	0.2722	3.7336*
AR(2)	-0.3576	-13.0268*
AR(3)	0.1071	4.0047*
AR(4)	0.3188	9.5275*
AR(5)	-0.5693	-8.5446*
MA(1)	-0.2472	-3.5857*
MA(2)	0.3042	17.9863*
MA(3)	-0.1344	-9.7736*
MA(4)	-0.3761	-12.0227*
MA(5)	0.5576	8.3098*
F-statistic	3.173*	p-value=0.0002
Box-Pierce Q for ε_t [1]	9.0839	p-value=0.982
Box-Pierce Q for ε_t^2	7.4300	p-value=0.995
Jarque-Bera statistic	10764	p-value=0.000
Skewness*	0.671	
Kurtosis*	17.055	
B-P-G test [2]	618.65	p-value=0.000

[1] For the May price series all diagnostic tests are performed on the errors, e_t.

[2] Breusch-Pagan-Godfrey (1979) test for heteroscedasticity.

Table 3. The GARCH (3,2) results for September contract

Dependent Variable: $\Delta \ln P$	Coefficient	t-statistic
Conditional Mean		
Constant	0.000362	0.8237
TRUN	0.0002759	5.8320*
AR(1)	-0.1018	-0.4457
AR(2)	-0.3017	-1.5200
AR(3)	-0.1717	-0.8856
AR(4)	0.5399	3.3570*
AR(5)	-0.4138	-2.5750*
MA(1)	0.1098	0.4676
MA(2)	0.2494	1.2720
MA(3)	0.1128	0.6595
MA(4)	-0.5502	-3.6750*
MA(5)	0.3906	2.4020*
Conditional Variance		
TRUN	-0.7175E-10	-0.1973E-03
α_0	0.3174E-05	3.2220*
α_1	0.2324	5.3710*
α_2	-0.2036	-4.1880*
α_3	-0.0205	-0.8625
β_1	0.963	11.5600*
β_2	0.003879	0.0491
Box-Pierce Q for v_t[1]	7.2719	p-value=0.996
Box-Pierce Q for v_t^2	0.0112	p-value=1.000
Jarque-Bera statistic	1285.4980	p-value=0.000
Skewness*	-0.1310	
Kurtosis*	7.8721	
B-P-G test	1302.00	p-value=0.000

[1] For the September price series all tests are performed on the normalized errors, v_t.

References

Akaike, H., "Likelihood of a Model and Information Criteria," *Journal of Econometrics* 16(1981) 3-14.

Blank, S.C., "Research on Futures Marekts: Issues, Approaches, and Empirical Findings," *Western Journal of Agricultural Economics* 14(1989)126-39.

Bollerslev, T., "On the Correlation Structure for the Generalized Autoregressive Conditional Heteroskedastic Process," Journal of Time Series Analysis 9(1988) 121-31.

__________"Generalized Autoregressive Conditional Heteroskedasticity," *Journal of Econometrics* 31(1986) 307-327.

Breusch, T.S. and Pagan, A.R., "A Simple Test for Heteroscedasticity and Random Coefficient Variation," *Econometrica* 47 (1979) 1287-94.

Commodity Trend Service (CTS), *How to Forecast with Futures Charts*. 1996.

Deaton, A. and G. Laroque, "On the Behavior of Commodity Prices," *Review of Economic Studies* 59(1992):1-23.

Dorfman, J.H., "Should Normality Be a Normal Assumption?" *Economics Letters* 42(1993): 143-147.

Frechette, D.L., "The Dynamics of Convenience and the Brazilian Soybean Boom," presented at 1995 Chicago Board of Trade Fall Research Seminar Proceedings.

Fujihara, R., and K. Park, "The Probability Distribution of Futures Prices in the Foreign Exchange Market: A Comparison of Candidate Processes," *The Journal of Futures Markets* 10(1990)623-641.

Hall, J., B.W. Brorsen, and S. Irwin, "The Distribution of Futures Prices: A Test of the Stable Paretian and Mixture of Normals Hypotheses," *Journal of Financial and Quantitative Analysis* 24 (1989) 105-116.

Hotelling, H. "The Economics of Exhaustible Resources," *Journal of Political Economy* 39(1931): 137-75.

Kaldor, N. "Speculation and Economic Stability," *Review of Economic Studies* 7(1939)1-27.

Keynes, J.M., "Some Aspects of Commodity Markets," *Manchester Guardian Commercial*, European Reconstruction Series, Section 13, pp. 784-86. 1921.

Lamoureux, C.G. and W.D. Lastrapes. "Heteroskedasticity in Stock Return Data: Volume versus GARCH effects." *The Journal of Finance* 45(1990) 221-229.

Lien, D.D., "The Inventory Effect in Commodity Futures Markets: An Empirical Study," *Journal of Futures Markets* 7(1987):637-52.

Myers, R.J. "Time Series Econometrics and Commodity Price Analysis: A Review," *Review of Marketing and Agricultural Economics* 62(1994).

Stein, Jerome L., "The Simultaneous Determination of Spot and Futures Price," *American Economic Review* 51(1961):1012-25.

Williams, J.B., "Speculation and the Carryover," *Quarterly Journal of Economics* 6(1935) 436-455.

Williams, J., "Futures Markets: A Consequence of Risk Aversion or Transaction Costs?" *Journal of Political Economy* 95(1987) 1000-23.

Williams, J.C. and B.D. Wright, *Storage and Commodity Markets*, NY: Cambridge University Press (1991).

Working, H., "The Theory of Price of Storage," *American Economic Review* 39 (1949) 1254-62.

Yang, S.R. and B.W. Brorsen, "Price Limits as an Explanation of Thin-Tailedness in Pork Bellies Futures Prices," *The Journal of Futures Markets* 15(1995): 45-59.