Investigation of Price Discovery and Efficiency for Cash and Futures Cotton Prices

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The dynamic relationship between daily cash and futures prices is investigated using time series analysis. The procedure involves causality tests between the two price series. The results show that futures price movements lead cash prices, implying that prices are discovered in the futures market.

The role of the futures market in price discovery and its impact on efficiency have been the subject of much research and controversy. Martin and Garcia concluded in their study that futures markets are not agencies for rational price formation. However, Just and Rausser presented evidence that the futures price is a good estimator of the cash price in a future time period. Grossman and Stiglitz showed the existence of an inefficient cash market is necessary for a successful futures market. Since transaction costs (e.g., storage, interest, commissions, transportation) are lower in the futures market, speculators with access to information are able to use their information to make a profit and at the same time aid in price discovery.

Leuthold and Hartman developed an econometric model designed to forecast hog prices using available public information as the norm against which futures prices were compared. They found that on occasion the econometric model pro-vided more accurate forecasts of subsequent prices than the futures market. They concluded that the live-hog futures market was not performing efficiently, presumably because of the market's inability to reflect all information.

Garbade and Silber concluded, "The evidence suggests that the cash markets for wheat, corn, and orange juice are largely satellites of the futures market for those commodities." However, Garbade and Silber found the pricing of silver, oats, and copper was more evenly divided between the cash and futures markets.

This paper also explores the role of the futures market in price discovery. Rather than compare future cash prices with current futures prices as most past studies have done, this study compares current cash and current futures prices. The dynamic relationship between cash and futures prices will imply whether cotton prices are discovered in cash markets, in the futures market, or if they are determined simultaneously. Tests of economic efficiency will be performed to determine which market is a more effective mechanism for price discovery.

Economic Efficiency

The concept of efficiency has many different meanings to economists. Sporleder

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and Chavas defined efficiency in terms of how quickly and accurately prices reflect changes in supply or demand. Panton defined an efficient market as one in which a speculator could not earn an "above normal" return. Fama defined an efficient market as one that fully reflects all available information. Fama developed his efficiency tests with respect to three information sets: 1) a strong form test which includes all information, including that available to insiders, 2) a semi-strong form test that includes all publicly available information, and 3) a weak form test where the information set consists of past prices. Fama's tests assume traders are risk neutral and transaction costs are zero. Danthine (1977) argued that the existence of high transaction costs may result in a price change in one market having no effect on a related market until the difference in price is sufficient to cover transaction costs and still yield normal returns to a trader. It has also been shown that if traders are risk averse then expected price differentials greater than transaction costs may exist across periods (Danthine, 1978; Leroy; Lucas). The assumption that transaction costs are zero may be reasonable for the futures market but, it is not for the cash market. The impacts of transaction costs must first be removed before applying the efficiency tests.

Tests of efficiency for this paper are performed in the weak form sense. The tests compare the efficiency of cash cotton prices and prices for nearby cotton futures contracts. Each price series is evaluated according to its efficiency in reflecting the information available in its own prices as well as that of the other series.

Structural Model

The structural model showing the relationship between cash and futures markets is developed in this section. In the subsequent discussion, capital letters are used to denote quantities and lower case

letters to denote prices. There are many forces acting in cash and futures markets. This model is designed to represent the dominant forces. A small percentage of producers hedge; thus the supply at the farm level should be relatively unaffected by futures prices. The supply in the cash market (C^s) is

$$C^s = g_1(c, x) \qquad (1)$$

where c is cash price and x is a set of exogenous shifters. A large portion of cotton processors hedge; thus the demand for cash cotton (C^d) would be a function of the futures price (f) and is specified as

$$C^d = g_2(c, f, y) \qquad (2)$$

where y is a set of exogenous shifters for cotton demand such as prices of synthetic fibers. In this discussion, futures supply represents participants with short positions (sellers) and demand represents those traders with long positions (buyers). Processors who hedge, buy in the cash market and sell on the futures market. Either supply in the futures market is derived from cash demand, or cash demand is derived from futures market supply or they are determined simultaneously. It is the purpose of this paper to ascertain if price is determined in cash markets or in the futures market and thus discover if one is a derived function. The futures market supply would be a function of the same variables as cash demand and is

$$F^s = g_3(c, f, y) \qquad (3)$$

The demand for futures contracts is largely a speculative demand and is

$$F^d = g_4(f, z) \qquad (4)$$

where z is a set of exogenous shifters. It is likely that z and x contain some of the same variables. The model is completed by equating supply and demand. We realize that speculators operate on both sides of the futures market and the cash market as well. It is the action of these speculators that forces the markets to an equilibrium.

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However, if the markets are inefficient, traders are risk averse, or transaction costs are high, the static model would not be appropriate. By equating supply and demand in each market and introducing time, we can solve equations (1)–(4) for the reduced form equations

$$\begin{bmatrix} c_t \\ f_t \end{bmatrix} = h(\theta_t) \qquad (5)$$

where $\theta = \{x, y, z\}$. If the static model is not appropriate, then (5) can be made dynamic to include effects of both current and past structural shifts

$$\begin{bmatrix} c_t \\ f_t \end{bmatrix} = q[\theta_t, \theta_{t-1} \dots .] \qquad (6)$$

Markets would be expected to reach a new equilibrium in a short period of time after a shock. It is impossible to measure all the components of θ (i.e., weather reports, textile sales, exports) on a daily basis; therefore the structural model is not useful for empirical work. An alternative to the structural approach is to assume prices are generated by an underlying stochastic process and attempt to model the process. This approach leads to the time series model:

$$\begin{bmatrix} c_t \\ f_t \end{bmatrix} = D + S + e_t \qquad (7)$$

where D is the deterministic portion, S is a mean and covariance stationary short memory process and e_t is white noise. The deterministic part D represents trend and seasonality components which do not include new information. The deterministic component (D) must be removed before using time series analysis and applying the efficiency tests. The stochastic process, $S + e_t$, represents the impact of new information. If S is zero, the market adjusts instantaneously and therefore it is efficient.

Data and Modeling Approach

The data used for the analyses presented here were obtained from Cotton Price Statistics (USDA). The cash price data are the closing quoted daily prices for cotton (grade 42 and staple 32) in Lubbock, Texas between June 15, 1976 and April 30, 1982. The futures data were closing prices for the New York cotton futures contracts over the same time period. As other researchers have suggested our futures price data is compiled using the prices for the dominant contract, i.e., the one with highest open interest (Dale and Workman; Gray and Nielsen). The reason for doing this is that only the nearby option is heavily traded and the other options are simply a spread from the nearby based on storage costs (Cunningham). In application of this procedure Irwin found that the dominant contract consistently switched a few days before the beginning of the delivery period. Following Irwin, our futures price data consist of a continuous series of nearby contracts with the last 30 days of each contract deleted.

The first step in the time series modeling approach is to remove (filter) the deterministic portion of the series. Economic data generally have trend components due to inflation. The solution used here is to first difference the data and thus model price changes. Fisher has argued for difference formulations when, as is the case here, the short-run nature of the process is of interest. First differencing does not remove seasonality unless the seasonal pattern is linear. No significant seasonality was found in the cotton price changes. This finding agrees with Smith who found no significant seasonality in cotton prices in the Lubbock area. To adjust for the possible effect of weekends, the data were standardized by day of the week using the mean and standard deviation for each day

TABLE 1. Mean and Standard Deviation for Changes in Cash Cotton Prices and Cotton Futures Prices, by Day of the Week.

	Cash	Cotton Futures
Monday		
$\bar{X}$[a]	0.0296	−0.1154
σ[b]	0.7195	1.0759
Tuesday		
$\bar{X}$	−0.0426	−0.1243
σ	0.5953	0.9085
Wednesday		
$\bar{X}$	−0.0231	0.0346
σ	0.4405	0.8485
Thursday		
$\bar{X}$	0.0189	−0.0284
σ	0.6814	0.8900
Friday		
$\bar{X}$	0.0603	0.1776
σ	0.5101	0.8733

[a] Mean change for day of the week (cents per pound).
[b] Mean standard deviation of change by day of the week (cents per pound).

(Table 1). No new information was assumed to become available on holidays; thus the correlation between the day before the holiday and the day after was assumed to be the same as if the holiday had not occurred. After this filtering process, the data are mean and covariance stationary and thus time series modeling may be used. The filtered data should reflect the impacts of new information.

The basic model used is a bivariate autoregressive (AR) model which is

$$Y(t) = \sum_{j=1}^{P} \begin{bmatrix} a_{11}(j) & a_{12}(j) \\ a_{21}(j) & a_{22}(j) \end{bmatrix} Y(t - j) \qquad (8)$$

where $Y(t)$ is a 2×1 vector of observations, p is the order of the autoregressive process and a_{ik} (i, k = 1, 2) are coefficients.

The prices are compared, two at a time, to compare the futures price to the cash price and vice versa. The order (p) of the AR process is identified using Akaike's Information Criterion (AIC) (Akaike). If the AIC selects the "true" order of the AR process and the residuals are uncorrelated, consistent and asymptotically efficient estimates of the parameters may be obtained using ordinary least squares. Since the sample size is approximately 1,500, large sample properties should be of interest. The residuals of the model were tested for white noise using Bartlett's Kolmogorov-Smirnov test (Fuller, pp. 285–87). The discontinuity in the futures prices was taken into account in the estimation procedure by using actual price changes in all cases.

Time series models can give insight into efficiency and price determination by examining causality and feedback relationships. Pierce and Haugh defined causality in terms of predictability: a variable X is said to cause a variable Y, if Y can be predicted better by using past values of X than if the information about X was not used. If X causes Y and Y does not cause X, then X is said to cause Y unidirectionally. Bivariate causality (X causes Y and Y causes X) is called a feedback relationship. Under the assumption that filtering removes all transaction costs, then unidirectional causality would imply the model could be used to generate profits and the market would be considered inefficient. Unidirectional causality also has implications for price determination. For example, if futures prices cause cash prices unidirectionally it would imply cotton prices are determined in the futures market.

The test for causality is performed using equation (8). If $a_{12}(j) = 0$ for all j then variable 2 does not cause variable 1 (Tjostheim). This test is performed not by examining the significance of individual coefficients but by testing the significance of the group as a whole. The test statistic has an F distribution under the null hypothesis of no causation (Judge *et al.*). This test procedure is a variant of Granger's test which three Monte Carlo studies have

shown to be more powerful than the causality tests of either Sims or Haugh (Guilkey and Salemi; Nelson and Schwert; Geweke *et al.*).

Results

The data were filtered according to the procedure described in the modeling section. The standard deviations were greater for the futures prices (Table 1). The standard deviations are greater on Monday, as expected, since there is more time for new information to become available over the weekend.

The AR model selected using the AIC was an AR(6). Since an AR(0) was not selected, some inefficiency is present, but the causality results must be examined to determine the nature of the inefficiency. Bartlett's Kolmogorov-Smirnov statistic indicates the residuals are white noise (Table 2). The cash price is significantly related at the 5 percent level to lagged futures prices as well as its own lagged values (Table 2), indicating the cash market is inefficient. The futures price is also inefficient since it is significantly related to its own lagged values. The futures price "causes" the cash price unidirectionally, implying cotton prices are discovered in the futures market. The cash price has a strong positive relationship with the futures price lagged one period indicating the price which is determined in the futures market is transferred to the cash market in a short period of time. The R-square for the cash price equation is larger than the one for futures prices, indicating more of the variation in cash prices is explained by past price changes and therefore the cash price is less efficient. These results have implications about the behavior of market participants. It appears that buyers base their cash bids on futures price quotes. However, the buyers are inefficient in incorporating the information from the futures markets, thus the resulting lag in price adjustments.

TABLE 2. Multivariate Autoregressive Model for Cotton Futures and Cash Cotton Prices.[a]

	Cash equation	Futures equation	
R-square	.039	.027	
Bartlett's Kolmogorov-Smirnov Statistic[b]	.0131	.0172	
Intercept	−.0004	−.0002	
	(−.02)	(−.00)	

Dependent Variable	Cash	Futures	Cash	Futures
Lag 1	−.071	.177	.001	.064
	(−2.43)[*c]	(6.15)[*]	(.02)	(2.23)[*]
Lag 2	−.017	.010	.042	−.064
	(−.61)	(.35)	(1.45)	(−2.21)[*]
Lag 3	.024	.020	.034	−.001
	(.84)	(.70)	(1.17)	(−.03)
Lag 4	.036	.044	.051	−.014
	(1.25)	(1.52)	(1.76)	(−.49)
Lag 5	.060	.032	.033	.007
	(2.07)[*]	(1.10)	(1.14)	(.26)
Lag 6	.044	−.065	.062	−.158
	(1.55)	(−2.24)[*]	(2.16)[*]	(−5.42)[*]
F-Value	2.33	7.77	1.90	6.52
Prob > F	[.029]*	[.0001]*	[.07]	[.0001]*

[a] t-values are in parentheses.
[b] Reject Ho: White Noise Residuals at the 5 percent level if the test statistic is greater than .0484.
[c] Asterisks denote significance at the 5 percent level.

Summary

This study examined price discovery and efficiency using Lubbock cash and New York futures cotton prices. The results apply only to the specific markets analyzed. The tests of efficiency considered a market that adjusted instantaneously to new information to be efficient. According to this restrictive definition of efficiency both the futures market and the cash market are inefficient. However, since it is not clear whether transaction costs were fully removed, it is not conclusive that the markets are inefficient. Futures price changes lead cash price changes indicating that cotton prices are discovered

in the futures market. Thus, the demand
at the farm level is derived from futures
market supply. The futures market has
more participants and lower transaction
costs; therefore it should be a more effi-
cient mechanism for price determination.

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