Asset Storability and Price Discovery in Commodity Futures Markets: A New Look

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This article examines the price discovery performance of futures markets for storable and nonstorable commodities in the long run, allowing for the compounding factor of stochastic interest rates. The evidence shows that asset storability does not affect the existence of cointegration between cash and futures prices and the usefulness of future markets in predicting future cash prices. However, it may affect the magnitude of bias of futures markets' estimates (or predictions) for future cash prices. These findings have several important implications for commodity production decision making, commodity hedging, and commodity price forecasting. © 2001 John Wiley & Sons, Inc. Jrl Fut Mark 21:279–300, 2001

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INTRODUCTION

Price discovery in futures markets is commonly defined as the use of futures prices to determine expectations of (future) cash market prices (Schroeder & Goodwin, 1991; Working, 1948). According to Black (1976), the primary benefits from commodity futures markets are informed production, storage, and processing decisions. Thus, the price discovery performance of commodity futures markets is crucial to the use of these markets.

In general, commodity futures markets can perform both storage facilitation and forward pricing roles in their price discovery function. However, because storable commodities such as grain have been important historically in developing futures markets, both theoretical and empirical research have focused on the storage facilitation role. The storage facilitation role is important to price discovery because arbitrage may work through storage. Without storage, arbitrage may not work effectively, and it might appear that there is no other economic force that links cash and futures prices together. In this case, it seems that futures prices and cash prices may be determined separately, and so it seems unlikely for futures prices to be an unbiased predictor of future cash prices. This line of research culminates with the carrying charge or cost-of-carry model, which provides insight for modeling the temporal relationship between cash and futures prices.

The forward pricing role of futures markets, which is relevant to both storable and nonstorable commodities, generally has been ignored. The lack of a storage facilitation role casts suspicion on price discovery performance in nonstorable commodity futures markets (Garbade & Silber, 1983; Purcell & Hudson, 1985; Skadberg & Futrell, 1966). Some researchers (Black, 1976; Peck, 1985) argued that the forward pricing role of futures markets may be sufficient to justify futures prices as an unbiased predictor for cash prices. Unfortunately, this argument has not received much serious attention. Much of the empirical literature before the early 1980s, as summarized in Kamara (1982, p. 268), states that an exact functional relationship exists between cash and futures prices for storable commodities as described by the cost-of-carry model, whereas no such exact relationship exists for nonstorable commodities.

More recently, recognizing a time series property (i.e., nonstationarity) for commodity prices, many researchers have used notions of cointegration (Engle & Granger, 1987) to investigate price discovery in futures markets. The statistical question in most works centers on whether there is cointegration between the cash and futures prices, which is necessary if futures prices are an unbiased predictor (Brenner & Kroner, 1995). As reviewed in the next section, researchers have found mixed evidence of cointegration between cash and futures prices for storable commodities. Some (Covey & Bessler, 1995; Fortenbery & Zapata, 1993) have argued that cointegration may depend on asset storability. These authors have argued that researchers should not expect cointegration between cash and futures prices for nonstorable commodities but should expect it for storable commodities. This argument is consistent with the extant literature, emphasizing the importance of the storage facilitation role in the price discovery of futures markets. Other researchers (Brenner & Kroner, 1995; Zapata & Fortenbery, 1996) have suggested that the empirical finding of no cointegration for storable commodities could be due to a misspecification problem, that is, the exclusion of possible nonstationary elements of the cost of carry, particularly stochastic interest rates in the cointegration system. These more recent empirical results and their explanations may strengthen the argument that the forward pricing role does not serve well for the price discovery of commodity futures markets. This may or may not be justified in a more thorough empirical analysis.

This article examines the price discovery of futures markets for storable and nonstorable commodities, allowing for the compounding factor of stochastic interest rates. It makes several contributions to the literature of futures markets. First, some new, although limited evidence is presented for the importance of the forward pricing role in price discovery in comparison with the storage facilitation role. Second, the possible differences in price discovery performance between storable and nonstorable futures markets are clarified in terms of being an unbiased estimate and a useful predictor. Finally, the interest rate issue in the empirical specification of the cost-of-carry model is further explored.

CONCEPTUAL FRAMEWORK

Past literature on the price discovery of commodity futures markets has concentrated on two questions about the temporal price relationship between futures and cash prices. First, are futures prices an unbiased estimate of future cash prices? This is known as an *unbiasedness hypothesis* (e.g., Brenner & Kroner, 1995). Second, are futures prices a useful predictor of future cash prices? That is, are futures markets, rather than cash markets, the primary point for price discovery? The second hypothesis is called the *prediction hypothesis*. Evidence of bias predictability sheds light on the rationality of futures prices (Peck, 1985, p. 61). Beginning with Working's seminal works in the 1940s, there has been widespread agreement among theorists that the storage facilitation role suggests positive answers to both questions. Unlike storable commodities, skepticism about the economic performance of futures trading in major nonstorable commodities (i.e., livestock) has been quite prevalent. Analysts have had difficulty visualizing futures trading for nonstorable commodities because of the lack of a concept similar to a carrying charge for storable commodities (Purcell & Hudson, 1985, p. 329). Many argue that futures markets for nonstorable commodities such as live cattle are not able to offer significant pricing potential (Leuthold, 1974; Skadberg & Futrell, 1966). However, other works (Black, 1976; Peck, 1985) demonstrate theoretically that the forward pricing role can justify positive answers to the two questions. Purcell and Hudson (p. 356) stated that the price discovery issue in nonstorable commodities is still obscure and confusing to many observers. Therefore, this issue should receive top priority in any discussion of livestock futures issues.

As for the earlier empirical literature, as summarized in Kamara (1982) and Purcell and Hudson (1985), relatively little evidence has been found in favor of price discovery functioning for nonstorable commodities. This may imply the failure of futures markets in serving the forward pricing role. In contrast, there is much favorable evidence for price discovery functioning for storable commodities. However, because cash and futures prices of commodities are usually nonstationary, traditional regression analysis applied in earlier studies may yield false results. To address the problem of nonstationary prices, researchers use cointegration techniques to investigate price discovery issues. Many cointegration-based empirical works only tested the unbiasedness hypothesis or part of it. These cointegration-based works on agricultural commodities include Baille and Myers (1991), Bessler and Covey (1991), Schroeder and Goodwin (1991), Fortenbery and Zapata (1993, 1997), Covey and Bessler (1995), Zapata and Fortenbery (1996), and Sabuhoro and Larue (1997). Similar work has also been done on other commodity markets (Quan, 1992; Schwartz & Szakmary, 1994). These researchers found mixed evidence for cointegration for storable commodities but no cointegration for nonstorable commodities. The results were also mixed for the leading informational role between cash and future prices.

The next paragraphs briefly discuss the theoretical models and empirical specifications underlying the cointegration-based price discovery studies. Brenner and Kroner (1995) provided additional details.

For a perfectly storable commodity, no arbitrage through storage implies the following relation holds in the long run:

$$F_{T|t} = (S_t + U)e^{r(T-t)} \tag{1}$$

where $F_{T|t}$ is the price of a futures contract at time t that expires at time T, S_t is the cash price at time t, r is the interest rate, and U is the present value of all other storage costs (including transportation, warehousing, and insurance costs but not interest cost) that will be incurred during the life of a futures contract. Because it is plausible to assume negligible U for a (perfectly) storable commodity over a reasonable period, the equation can be transformed as follows after a logarithm has been performed on both sides:

$$\ln F_{T|t} = \ln S_t + r(T - t) \tag{2}$$

A possibility that misspecification arises in the bivariate analysis of cash and futures prices for storable commodities was noted by Brenner and Kroner (1995) and Zapata and Fortenbery (1996), among others. They argued that the results of such cointegration tests depend entirely on the time series properties of the cost of carry. Specifically, the interest rate is recognized as an important and most likely nonstationary part of the cost of carry. They argued that failure to find cointegrated cash and futures prices for storable commodities may be due to interest rates with a stochastic trend during the sample period. For a stochastic interest rate, cash and futures prices could drift apart in the long run and thus not be cointegrated. However, when the stochastic interest rate is also included in the cointegration system, the three variables (futures price, cash price, and interest rate) may be cointegrated. The first empirical study that explored the role of the stochastic interest rate in such a cointegration context was conducted by Zapata and Fortenbery.

The interest cost $r(T - t)$ but not the interest rate r should be used in the cointegration analysis of cash and futures prices. One should not assume that $r(T - t)$ and r have the same time series behavior because $T - t$ represents the time to maturity and is not a constant. The variable $r(T - t)$ may be stationary even if the variable r is nonstationary. Hence, the time series property of the interest cost $r(T - t)$ may affect the way to model it. If the interest cost is nonstationary, it should be included in the cointegration analysis of cash and futures prices. Even if the interest cost is stationary, we should not ignore it. Although the exclusion of a stationary interest cost does not affect cointegration rank, it may affect the other aspects of cointegration analysis, including the estimation and inference of cointegrating vectors, the constancy of cointegration relation, and the forecasting performance of cointegration models. In agreement with Garbade and Silber (1983), regardless of interest cost stationarity, the following cash-equivalent futures price replaces the original futures prices in the cointegration analysis:

$$\ln(\text{cash-equivalent futures price}) = \ln(\text{futures price}) - r(T - t)/360 \quad (3)$$

Thus, the theory-consistent empirical specification for storable commodities is as follows:

$$\ln F_{T|t} - r(T - t)/360 = u + \ln S_t + e_t \quad (4)$$

where u is a constant, as discussed in more detail shortly.

For nonstorable commodities, forward pricing is the only economic role of futures markets. Forward pricing refers to the notion that anticipated supply and demand is reflected in futures market prices. The unbiased forward pricing of futures markets can remedy the problem of resource misallocation that would exist without futures markets and thus help rationalize production decisions and optimal allocation of productive resources (Stein, 1981). Peck (1985, p. 60) pointed out that the forward pricing function may also play at least as an important role as the storage facilitation role for storable commodities.

The forward pricing role suggests that the following relationship between cash and futures prices will hold:

$$F_{T|t} = E_t(S_T) \text{ or } F_{T|t} = S_T + e_T \quad (5)$$

where $F_{T|t}$ is the price of a futures contract at time t that expires at time T, S_T is the cash price at time T, E_t is the expectation operator applied at time t, and e_T is white noise. Assuming the first difference of S_t is stationary with a constant mean, the following empirical specification for nonstorable commodities is obtained (see Brenner & Kroner, 1995, for a proof of equivalence between Equations 5 and 6):

$$F_{T|t} = u + S_t + e_T \quad (6)$$

where u is a constant.

Equations 1 to 6 form the framework for our cointegration analysis of the futures price discovery function. The unbiasedness hypothesis implies cointegration and a cointegrating vector (1, −1) between cash and futures prices (e.g., Brenner & Kroner, 1995). The validity of the unbiasedness hypothesis testing in this context depends on the assumption that other components of cash and futures price differentials (except interest cost) are stationary variables, as captured by the constant item u in Equations 4 and 6. If those components that may be captured by u (e.g., transactions costs, storage costs, and local basis effects) are proportional to (nonstationary) prices, parameter estimates of the cointegrating vector may be affected, thus influencing the unbiasedness test results.[1] Also, the constant $u = 0$ is not imposed for testing the unbiasedness hypothesis in this study for two reasons. First, there may exist a constant risk premium that may be captured by $u \neq 0$ (Beck, 1994; Hamilton, 1992). Second, even assuming risk neutrality (i.e., no risk premium), the location difference between commodity cash and futures markets may imply certain transportation costs that can also be measured by $u \neq 0$ (Hamilton, 1992). As noted previously, the unbiasedness hypothesis determines if the futures prices are rational forward prices, thus creating desirable welfare effects. The prediction hypothesis concerns the informational causality between cash and futures prices in these equations or, equivalently, the relative pricing efficiency in futures markets and cash markets. The importance of futures market in price discovery may depend largely on its relative efficiency (Purcell & Hudson, 1985, p. 351). Controversy also exists over the efficiency issue, particularly for nonstorable commodities. For example, Peck (1985, p. 63) argued that the price in futures markets for nonstorable commodities, if rational (in the sense of unbiasedness), may not be informationally efficient. However, using probabilistic forecasting methods, Covey and Bessler (1992) showed that the nearby live cattle futures prices (fully Granger) caused the daily cash slaughter cattle price, and there was little evidence of feedback from cash prices to futures prices.

ECONOMETRIC METHODOLOGY AND HYPOTHESIS

Cointegration analysis is conducted following the maximum likelihood estimation procedure developed by Johansen (1991) and Johansen and Juselius (1990). The vector X_t is defined as consisting of p variables. These variables in X_t are assumed to be integrated of order one, denoted by I(1). If p ($p = 2$ in this study) variables in X_t [$X_t = (C\ F)'$ in this study, where C stands for cash prices and F stands for cash-equivalent futures prices] are cointegrated, it can be expressed by a vector autoregressive model with k lags:

$$X_t = \sum_{i=1}^{k} \Pi_i X_{t-i} + \mu + e_t \ (t = 1 \ldots T) \tag{7}$$

Equation 1 can be rewritten as a reduced form error correction model (ECM):

[1]We thank the reviewers for this insightful comment.

$$H_0\text{: } \Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \mu + e_t \ (t = 2 \ldots T) \quad (8)$$

The first necessary condition for the unbiasedness hypothesis is cointegration between the cash and (cash-equivalent) futures prices, with proper allowance for interest rates for storable commodities (see Equation 3). Cointegration can be tested by the number of cointegration relations, r, as follows:

$$H_1(r)\text{: } \Pi = \alpha\beta' \quad (9)$$

where $\alpha\beta' = (\alpha_1 \ \alpha_2)' \ (\beta_1 \ \beta_2)$. A trace test is conducted to test the null hypothesis that there are (at most) r $(0 \leq r \leq p)$ cointegrating vectors. The trace test statistic is as follows:

$$\text{Trace} = -T \sum_{i=r+1}^{p} \ln(1 - \lambda_i) \quad (10)$$

where T is the number of observations and λ_i is the $p - r$ smallest squared canonical correlation of X_{t-1} with respect to ΔX_t, corrected for lagged differences (also called *eigenvalues*).

Testing the rank of Π requires one to clarify how μ enters into the ECM (Equation 8), either as a constant in the cointegrating vector in the ECM or as a time trend in the original levels' representation (Equation 7). To deal with this problem, Johansen (1992) proposed a sequential hypothesis testing procedure with respect to the rank of Π. If there was a linear trend in the model, this hypothesis was labeled $H_1(r)$. This hypothesis was an unrestricted case. If there was no linear trend in the model, the hypothesis was labeled $H_1(r)^*$, which was restricted. The sequential hypothesis testing procedure suggests testing hypotheses in the following order: $H_1(0)^*$, $H_1(0)$, $H_1(1)^*$, $H_1(1)$ ... $H_1(p)^*$, $H_1(p)$. We stop testing and accept the associated hypothesis regarding both the cointegration rank and linear trend after the first rejection fails.

The second necessary condition for the unbiasedness hypothesis can be formulated as statistical tests with respect to the cointegrating vector $\beta' = (\beta_1 \ \beta_2) = (1 \ -1)$. Mathematically, the hypothesis testing can be expressed as

$$H_2|H_1 : R'\beta = 0 \quad (11)$$

where $R' = (1 \ 1)$ for the unbiasedness hypothesis. The appropriate likelihood ratio (LR) test statistics are generally as follows:

$$LR = T \sum_{i=1}^{r} \ln[(1 - \lambda_{H0,i})/(1 - \lambda_i)] \quad (12)$$

The prediction hypothesis can be formulated as statistical tests with respect to the loading matrix $\alpha = (\alpha_1\ \alpha_2)'$. The hypothesis is equivalent to testing for cointegrated cash and futures prices: (1) $\alpha_2 = 0$ if the futures price leads the cash price, or $\alpha_1 = 0$ if the cash price leads the futures price in the long run, and (2) there is a bidirectional long-run information flow between cash and futures prices, that is, $\alpha_1 \neq 0$ and $\alpha_2 \neq 0$. The latter case is particularly interesting in further testing the possibility that futures markets are at least as important as cash markets in generating price information in the long run, that is, $|\alpha_2| \leq |\alpha_1|$. The statistical hypothesis is framed as follows:

$$H_3|H_2 : B'\alpha = 0 \quad (13)$$

where $B' = (1\ 0)$ (or $(0\ 1)$) if X_{1t} (or X_{2t}) is a weakly exogenous series for Case 1 or $B' = (1\ 1)$ for Case 2. A weakly exogenous series is a primary source of information in the long run and unidirectionally causes movement in the other series. In agreement with Zapata and Rambaldi (1997), the prediction hypothesis should be tested jointly with the restrictions readily imposed by the unbiasedness hypothesis. The appropriate LR test statistics are similar to Equation 12.

DATA

The data for this study are cash and nearby futures prices for storable commodities, including corn, oat, soybean, three major types of wheat (soft red wheat with the futures contracts traded on the Chicago Board of Trade, hard winter wheat with the futures contracts traded on the Kansas City Board of Trade, and spring wheat with the futures contracts traded on the Minneapolis Grain Exchange), cotton, and pork bellies, and nonstorable commodities, including hog, live cattle, and feeder cattle.[2] The 3-month Treasury bill rate is also studied. Datastream International provided all data. The study period of 6.5 years is from January 1, 1992 to June 30, 1998, covering the most market-oriented prices avail-

[2]The nearby futures prices for hog are based on live hog contracts through the December 1996 contract. With the February 1997 contract, a lean hog futures contract replaced the live hog contract as the primary hog futures contract traded on the Chicago Mercantile Exchange. Thus, since February 1997, the lean hog futures price data are used. Live hog data have been adjusted to correspond to lean hog futures. This change in the futures contract specification can only bias against finding cointegration, which makes the results of this study more robust.

able. Partial production flexibility was first introduced into the U.S. farm policy in the 1990 Food, Agricultural, Conservation and Trade (FACT) Act and was more fully expanded in the 1996 Federal Agricultural Improvement and Reform (FAIR) Act. To allow for the possible additional effect on the cointegration relationship of the 1996 FAIR Act, the study period can be divided into two periods, that is, before the FAIR Act (January 1, 1992 to March 31, 1996) and after the FAIR Act (April 1, 1996 to June 30, 1998).[3] The nearby futures price series are constructed as follows. First, the nearby futures contract, which is a contract with the nearest active trading delivery month to the day of trading, is specified. Prices for the nearby futures contract are used until the contract reaches the first day of the delivery month.[4] Then, prices for the next nearby contract are used. The nearby futures contract is used because it is highly liquid and the most active. On the basis of this theoretical framework, prices for storable commodities are transformed to a natural logarithm, but prices for nonstorable commodities are in their original form (the results for nonstorable commodities with the natural logarithm of prices are similar).

EMPIRICAL RESULTS

Two standard unit-root test procedures are applied to examine whether cash prices, futures prices (in natural logarithm for storable commodities), interest rates, and interest costs are nonstationary. The null hypothesis for both procedures is that a unit root exists. If the test statistics

[3]The fact that government farm programs can distort agricultural cash and futures price relationships (Crain & Lee, 1996; Shonkwiler & Maddala, 1985) has not yet received attention in the cointegration-based literature. Although U.S. farm policies did not directly regulate the market price, it affected agricultural market prices via several price-support tools, including deficiency payments and market loan rates. These price-support tools were closely tied to production inflexibility in that farmers had to plant certain crops required by the government to be qualified for government price supports. As shown by Shumway, Smith, and Richardson (1995) and Shonkwiler and Maddala, the lack of production flexibility and the associated price support in the previous U.S. farm policies distorted the market price by distorting the supply side of agricultural products. Furthermore, it is also well known that changes in the supply side of agricultural prices usually dominate the market price in the long run, whereas changes in the demand side of the agricultural prices are usually temporary (e.g., Bessler & Brandt, 1991). Thus, the distorted supply curve would yield agricultural (cash and futures) prices that may be quite different from free-market prices. This may cause cash and futures price linkage, as determined by free-market forces, to break even in the long run, which may result in a lack of cointegration. Because there was little production flexibility for U.S. major crops before the 1990 FACT Act, the lack of cointegration may be induced by the less market-oriented agricultural prices used in the previous studies.

[4]We also addressed the concern of a possible periodic price jump in the nearby futures price time series when a nearby contract rolls over to the next nearby contract. The existence of such a price jump could equally bias against finding cointegration in either subperiods. Hence, it does not seem to affect substantially our inference derived from cointegration analysis in two subperiods.

are smaller than the corresponding critical values, the null hypothesis may be rejected. One test is the augmented Dickey–Fuller test (Dickey & Fuller, 1979, 1981). The second test procedure was proposed by Phillips and Perron (1988). Lag lengths on each test are determined by the AIC + 2 rule; the lags are determined via selection of the minimum AIC (Akaike information criterion) plus 2 (Pantula, Gonzalez-Farias, & Fuller, 1994). Both tests consider cases with trend and without trend. The results (not reported here but available on request) show that each cash and futures price is I(1) in both periods at the 5% significance level. The interest rate series is stationary in the second period but nonstationary in the first period. In contrast, interest costs for all storable commodities are stationary in both periods. Note that the I(1) property of futures prices and the I(0) property of interest cost guarantee the I(1) property of cash-equivalent futures prices for storable commodities. Cash-equivalent futures prices for storable commodities will be used in place of futures prices for the following cointegration analysis.

The test results of cointegration on the unbiasedness hypothesis are listed in Tables I and II. The optimal lags in trace tests as well as in ECM estimations are selected by the minimization of the AIC. Minimization of the Schwarz Bayesian information criterion is also employed to select alternative lags and double-check the robustness of the empirical findings. At the 5% significance level, cointegration ($r = 1$) is found between cash and futures prices for all three nonstorable commodities (hog, live cattle, and feeder cattle) in both periods. This suggests that both cash and futures prices for nonstorable commodities share certain long-run information. This contrasts with no cointegration found for nonstorable commodities by Bessler and Covey (1991; live cattle), Schroeder and Goodwin (1991; hog), and Covey and Bessler (1995; live cattle).

Cointegration is also found in the first period for five (corn, oat, soybeans, cotton, and pork bellies) out of eight storable commodities at the 5% significance level and one more (hard wheat) at the 10% significance level. In the second period, a temporary disruption of cointegration between cash and futures prices for two commodities (cotton and live cattle) is observed immediately after April 1, 1996, lasting from 0.5 to 1 year. Thus, the first 1-year period after April 1, 1996 is excluded for these commodities in the cointegration analysis. Cointegration was found for six (corn, oat, soft red wheat, winter wheat, cotton, and pork bellies) out of eight storable commodities at the 5% significance level and one more (hard wheat) at the 10% significance level. The finding of no cointegration for soybeans and hard wheat at the 5% level even in the second subperiod may reflect the fact that these commodities are traded largely in inter-

TABLE I

Trace Tests on Cointegration Between Cash and Futures Prices (January 1, 1992 to March 31, 1996)

Without Linear Trend				*With Linear Trend*		
T	*C*(5%)	*Decision*	$H_0 = r$	*T*	*C*(5%)	*Decision*
			Corn (Lags = 2)			
30.68**	20.17	R	0	28.52**	15.20	R
1.20	9.09	F	1	0.01	3.96	
			Oat (Lags = 3)			
29.31**	20.17	R	0	28.11**	15.20	R
1.21	9.09	F	1	0.05	3.96	
			Soybeans (Lags = 3)			
29.42**	20.17	R	0	28.50**	15.20	R
3.14	9.09	F	1	2.24	3.96	
			Wheat1 (Lags = 4)			
16.04	20.17	F	0	15.76	15.20	
1.56	9.09		1	1.41	3.96	
			Wheat2 (Lags = 3)			
19.64*	20.17	F/R	0	19.06	15.20	
0.72	9.09		1	0.25	3.96	
			Wheat3 (Lags = 2)			
10.92	20.17	F	0	10.61	15.20	
1.42	9.09		1	1.09	3.96	
			Cotton (Lags = 4)			
30.03**	20.17	R	0	29.23**	15.20	R
2.12	9.09	F	1	1.61	3.96	
			Pork Bellies (Lags = 2)			
39.13**	20.17	R	0	38.39**	15.20	R
3.02	9.09	F	1	2.29	3.96	
			Hogs (Lags = 2)			
27.82**	20.17	R	0	27.43**	15.20	R
5.78	9.09	F	1	5.40	3.96	
			Live Cattle (Lags = 7)			
25.72**	20.17	R	0	25.42**	15.20	R
3.11	9.09	F	1	2.82	3.96	
			Feeder Cattle (Lags = 2)			
32.43**	20.17	R	0	29.97**	15.20	R
2.91	9.09	F	1	0.88	3.96	

Note: The critical values are from Tables A1 and A3 in Johansen and Juselius (1990). *r* is the number of cointegrating vectors. *T* is the trace test statistic. *C* is the trace test critical value. R and ** indicate that we reject the null hypothesis that the number of cointegrating vectors was less than or equal to *r* at the 5% level. F indicates that the null hypothesis fails to be rejected at either the 5% or 10% level. F/R and * indicate that the null hypothesis fails to be rejected at the 5% level but can be rejected at the 10% level.

TABLE II

Trace Tests on Cointegration Between Cash and Futures Prices (April 1, 1996 to June 30, 1998)

Without Linear Trend				*With Linear Trend*		
T	*C(5%)*	*Decision*	$H_0 = r$	*T*	*C(5%)*	*Decision*
			Corn (Lags = 5)			
21.06**	20.17	R	0	19.19**	15.20	R
4.73	9.09	F	1	3.15	3.96	
			Oat (Lags = 3)			
31.11**	20.17	R	0	28.27**	15.20	R
5.37	9.09	F	1	2.84	3.96	
			Soybeans (Lags = 1)			
16.92	20.17	F	0	16.71	15.20	
2.47	9.09		1	2.26	3.96	
			Wheat (Chicago Board of Trade) (Lags = 3)			
21.88**	20.17	R	0	19.17**	15.20	R
3.47	9.09	F	1	0.78	3.96	
			Wheat (Kansas City Board of Trade) (Lags = 2)			
18.22*	20.17	F/R	0	15.23	15.20	
3.09	9.09		1	1.41	3.96	
			Wheat (Minneapolis Grain Exchange) (Lags = 2)			
25.60**	20.17	R	0	24.81**	15.20	R
3.25	9.09	F	1	2.48	3.96	
			Cotton (Lags = 2)			
23.73**	20.17	R	0	23.58**	15.20	R
4.98	9.09	F	1	4.94	3.96	
			Pork Bellies (Lags = 2)			
21.27**	20.17	R	0	21.14**	15.20	R
1.97	9.09	F	1	1.87	3.96	
			Hogs (Lags = 3)			
25.60**	20.17	R	0	24.89**	15.20	R
1.71	9.09	F	1	1.12	3.96	
			Live Cattle (Lags = 6)			
20.63**	20.17	R	0	19.16**	15.20	R
1.85	9.09	F	1	0.94	3.96	
			Feeder Cattle (Lags = 5)			
20.59**	20.17	R	0	19.13**	15.20	R
4.21	9.09	F	1	2.85	3.96	

Note: The critical values are from Tables A1 and A3 in Johansen and Juselius (1990). *r* is the number of cointegrating vectors. *T* is the trace test statistic. *C* is the trace test critical value. R and ** indicate that we reject the null hypothesis that the number of cointegrating vectors was less than or equal to *r* at the 5% level. F indicates that the null hypothesis fails to be rejected at either the 5% or 10% level. F/R and * indicate that the null hypothesis fails to be rejected at the 5% level but can be rejected at the 10% level.

national markets. It has been noted that an important difference exists between commodity cash and futures markets in the ability of incorporating relevant price information (Crain & Lee, 1996; Yang & Leatham, 1999). Crain and Lee observed that the commodity cash market is for immediate delivery, and suppliers and buyers on the cash market may not have time to respond to price information. Yang and Leatham provided the supportive evidence for the argument, documenting that one equilibrium price was searched out across the three U.S. wheat futures markets, whereas no cointegration was found in the three comparable cash markets. Arguably, this difference between commodity cash and futures prices may be more significant for the commodities traded largely in the international markets. The futures prices for these commodities may aggregate international price information, whereas the cash prices for these commodities, which are from a U.S. regional cash market in this study, may consistently fail to absorb most of the price information from international markets. In addition, if the natural logarithm of futures prices and the natural logarithm of cash prices are used, cointegration for all eight storable commodities is found at the 5% significance level in the second period.

Overall, in comparison with previous studies, more market-oriented government farm policies during the period 1992 to 1998, together with a more liberalized international trade environment during this period, may help explain cointegration between cash and futures prices. It is also important to note that cointegration between cash and futures prices for nonstorable commodities occurred as frequently as for storable commodities. Thus, contrary to Fortenbery and Zapata (1993) and Covey and Bessler (1995), asset storability does not affect the existence of cointegration. The results (not reported here) from alternative specifications of prices (i.e., level prices for storable commodities and log prices for nonstorable commodities) are mixed but largely similar.

On the basis of cointegration being found at the 5% significance level, LR tests were conducted for $\beta' = (C\ F) = (1\ \ -1)$ (an unrestricted constant in the cointegration space is ignored). This is the unbiasedness hypothesis. Results are given in Table III. The LR test statistics show that the hypothesis cannot be rejected for hogs in both periods at the 5% significance level. However, $\beta' = (1\ \ -1)$ is rejected for live cattle and feeder cattle in both periods at any conventional significance level. The hypothesis cannot be rejected for three storable commodities (oats, soybeans, and pork bellies) in the first period and for all six commodities (corn, oats, soft red wheat, spring wheat, cotton, and pork bellies) in the second period (except corn at $p = 0.03$). Thus, emphasizing the more

TABLE III

Likelihood Ratio Test Results of Unbiasedness Hypothesis $H_2{:}\beta' = (1\ -1)$

Commodity	χ^2	*p Value*	*Final Beta Estimates (5%)*
	January 1, 1992 to March 31, 1996		
Corn	13.27(1)	0.00	(1 −1.11)
Oat	3.20(1)	0.07	(1 −1)
Soybeans	3.08(1)	0.08	(1 −1)
Cotton	7.15(1)	0.01	(1 −1.13)
Pork Bellies	0.82(1)	0.36	(1 −1)
Hog	1.69(1)	0.19	(1 −1)
Live Cattle	4.24(1)	0.04	(1 −1.25)
Feeder Cattle	14.38(1)	0.00	(1 −1.33)
	April 1, 1996 to June 30, 1998		
Corn	4.69(1)	0.03	(1 −1.21)
Oat	0.53(1)	0.47	(1 −1)
Wheat (Chicago Board of Trade)	0.52(1)	0.47	(1 −1)
Wheat (Minneapolis Grain Exchange)	0.50(1)	0.48	(1 −1)
Cotton	3.84(1)	0.05	(1 −1)
Pork Bellies	0.12(1)	0.73	(1 −1)
Hog	1.91(1)	0.17	(1 −1)
Live Cattle	5.74(1)	0.02	(1 −1.66)
Feeder Cattle	9.22(1)	0.00	(1 −1.48)

representative results in the second subperiod, one can summarize that futures prices are more likely to be an unbiased estimate of cash prices in the long run for most storable commodities than for most nonstorable commodities.

The prediction hypothesis is further tested on the basis of cointegration found at the 5% significance level (i.e., all commodities are considered for which cointegration was found). The results are reported in Table IV. As suggested by Zapata and Rambaldi (1997), the prediction hypothesis and unbiasedness hypothesis are jointly tested for commodities for which the unbiasedness hypothesis has not been rejected. Failure to reject the joint hypothesis indicates the futures price is an unbiased predictor of the future cash price. The hypothesis that futures prices are the primary informational sources of cash prices in both periods fails to be rejected for three nonstorable commodities. The exceptions are for hogs in the first period and feeder cattle in the second period, where the futures market is just as important as an informational source as the cash market. As noted previously, the equal importance of futures and cash markets as an informational source in the long run is defined as $|\alpha_2| = |\alpha_1|$. In contrast, futures prices for the storable commodities are found to be the primary information source for all five in the first period, except

TABLE IV

Likelihood Ratio Test Results of Prediction Hypothesis $H_3{:}B'\alpha = 0$

Commodity	*Hypothesis*	χ^2	*p Value*
	January 1, 1992 to March 31, 1996		
Corn	F → C	3.35(1)	0.06
Oat	F → C	5.62(2)	0.06
Soybeans	F → C	3.64(2)	0.16
Cotton	F → C	3.29(1)	0.07
Pork Bellies	F ⇔ C	3.07(2)	0.22
Hog	F ⇔ C	1.86(2)	0.39
Live Cattle	F → C	0.07(1)	0.80
Feeder Cattle	F → C	1.02(1)	0.31
	April 1, 1996 to June 30, 1998		
Corn	F → C	0.19(1)	0.66
Oat	F → C	4.96(2)	0.08
Wheat (Chicago Board of Trade)	F → C	4.95(2)	0.08
Wheat (Minneapolis Grain Exchange)	F ⇔ C	0.52(2)	0.77
Cotton	F ⇔ C	0.70(1)	0.40
Pork Bellies	F → C	0.51(1)	0.78
Hog	F → C	1.69(1)	0.19
Live Cattle	F → C	4.70(2)	0.10
Feeder Cattle	F ⇔ C	0.28(1)	0.60

Note: → denotes unidirectional information flow, and ⇔ denotes bidirectional information flow with equal importance.

for pork bellies, where the futures market and cash market are equally important informational sources. They are also the primary information source for all six in the second period, except for spring wheat and cotton, where the futures market and cash market are equally important informational sources. Overall, there is strong evidence to support the theory that futures prices lead cash prices (in the sense of price changes) in the long run (or are at least equally important as informational sources as the cash prices) in commodity markets.

Finally, a diagnosis check is conducted on the residuals from the aforementioned estimations. Particularly, the LaGrange multiplier test and Ljung–Box Q test statistics ensure that the residuals of Maximum Likelihood (ML) estimation are not autocorrelated. Furthermore, little skewness was found in the residuals for all commodities, but excess kurtosis and mild Autoregressive Conditional Heteroscedasticity (ARCH) effects remained for some commodities, which may not seriously affect the validity of the cointegration analysis (Gonzalo, 1994; Lee & Tse, 1996). With all the aforementioned findings combined, there is evidence that the price discovery function may work to a certain extent on nonstorable commodity futures markets in the long run, although not as well as on storable commodity futures markets. Moreover, the findings suggest that the forward pricing role may be moderately effective but may not serve the price discovery function of futures markets as well as the storage facilitation role.

IMPLICATIONS AND DISCUSSIONS

The findings in this study have many implications for market participants and the direction of future research. Some of the most important ones are enumerated as follows.

First, the findings from this study caution producers against using futures prices in making production decisions, particularly for livestock. In a pioneering article, Gardner (1976) suggested using futures prices for expectations in agricultural markets because futures prices reflect the market's estimate of the next period's cash price. Holthausen (1979) provided further support for Gardner's argument. Results from this study offer mixed evidence with respect to this recommendation. Futures prices for most storable commodities in this study (after the FAIR Act) are an unbiased predictor of future cash prices in the long run. However, consistent with Nerlove and Bessler's (2001) discussion, livestock futures markets do not capture all of the important long-run information for subsequent cash prices. This study shows that prices on most livestock futures markets are not unbiased estimates of future cash prices in the long run. Thus, livestock (particularly cattle) producers may be misled into a costly decision if they make production decisions only on the basis of futures prices without any adjustment.

Second, this study's findings regarding prevalent cointegration between cash and futures prices on commodity markets suggest that cointegration should be incorporated into commodity hedging decisions. Many recent empirical studies on financial markets (Ghosh, 1995; Ghosh & Clayton, 1996; Kroner & Sultan, 1993) have shown that hedge ratios and hedging performance may change considerably (and, more specifically, that hedge ratios are underestimated) if cointegration between cash and futures prices is mistakenly omitted from the statistical model. Allowance for the existence of cointegration is argued to be an indispensable component when comparing ex post performance of various hedging strategies, even if the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) effect is considered (Lien, 1996; Lien & Lou, 1994). This is also consistent with the theoretical argument that the relationship between the forward (futures) price and the expected price may affect the firm's optimal hedging decision, as shown in Holthausen (1979).

Third, evidence of prevalent cointegration on commodity markets suggests opportunities to improve the commodity price forecasts, particularly long-run forecasts. The literature (Engle & Yoo, 1987; LeSage, 1990; Lin & Tsay, 1996) has shown that ECMs resulting from cointegration should produce superior forecasting ability for longer horizons over the Vector Autoregression (VAR) without the error correction term. Particularly, the error correction term has been found to be statistically significant in explaining the cash prices for a majority of the commodities under study. Thus, adding the term should improve forecasts of the future cash commodity prices conditional on the current futures prices.

CONCLUDING REMARKS

We investigated price discovery performance of U.S. agricultural commodity futures markets in the long run. Special attention was paid to the role of asset storability, with an allowance made for compounding factors (short-run deviation and stochastic interest rate) ignored in most previous studies. The allowance of these compounding factors is important for conducting a more thorough analysis and making a more robust inference.

The results substantially improve our understanding of price discovery in commodity futures markets. Our findings indicate that asset storability does not affect the existence of a long-run relationship (i.e., cointegration) between cash and futures prices, which challenges previous empirical results (Covey & Bessler, 1995; Fortenbery & Zapata, 1993; Kamara, 1982). Recent evidence supports the fact that the forward pricing role may serve price discovery on commodity markets (Black, 1976; Peck, 1985). Consistent with this finding, in this study futures markets share and provide certain long-run price information to cash markets for all nonstorable commodities during both sample periods. However, futures prices were not unbiased estimates for cash prices for two out of three nonstorable commodities. Nevertheless, as explained previously, the findings regarding unbiasedness depend on the assumption that the item u in Equations 4 and 6 is stationary and can adequately capture other components of cash and futures price differentials. The findings disagree somewhat with the prevalent suspicion that a price discovery function would not work at all for nonstorable commodities because of the lack of storage. However, it also cautions against the naive use of futures prices as expected cash prices for most livestock commodities.

An interesting exception here is that the hog futures market apparently behaves more efficiently than both live and feeder cattle markets. Bessler and Brandt (1991), who compared livestock futures prices and an expert opinion as cash price forecasts, also supported this finding. Skadberg and Futrell (1966) provided a possible explanation, in that the hog market involves certain regular storage patterns for some pork products, whereas there is little storage of beef in cattle markets. In contrast, for most (five or six out of eight) storable commodities, particularly in the most recent market-oriented market environment after the FAIR Act, futures markets provide both an unbiased and predictive signal of cash prices. This manifests the economic significance of using futures markets to guide the production of storable commodities because it results in optimal resource allocation in the welfare sense (Stein, 1981). In addition, the results appear to be consistent across the two subperiods of our analysis, before and after the 1996 FAIR Act.

In summary, asset storability may not affect the cointegration and usefulness of future markets in predicting cash prices, but it may affect the magnitude of bias of the futures markets' estimates (or predictions) of cash prices. In this study, the price discovery performance for storable commodities is somewhat better than that for nonstorable commodities. Further research may be extended to examine this question with other nonagricultural commodity data. Finally, it is not yet certain which way is more appropriate in the implementation of the cost-of-carry model, to treat the interest rate as a separate variable or to treat the interest cost with the cash-equivalent relationship.[5] Future studies may be needed to explore this issue further regarding the role of stochastic interest rate, as raised by Zapata and Fortenbery (1996).

BIBLIOGRAPHY

Baille, R. T., & Myers, R. J. (1991). Bivariate GARCH estimation of the optimal commodity futures hedge. Journal of Applied Econometrics, 6, 109–124.

Beck, S. E. (1994). Cointegration and market efficiency in commodity futures markets. Applied Economics, 26, 249–257.

Bessler, D. A., & Covey, T. (1991). Cointegration. Some results on U.S. cattle prices. Journal of Futures Markets, 11, 461–474.

Bessler, D. A., & Brandt, J. A. (1991). An analysis of forecasts of livestock prices. Journal of Economic Behavior and Organization, 18, 249–263.

Black, F. (1976). The pricing of commodity contracts. Journal of Financial Economics, 3, 167–179.

[5]We thank a reviewer for this comment. According to Footnote 2 in Zapata and Fortenbery (1996), these two treatments sometimes may lead to similar conclusions on the cointegration rank. However, they may lead to quite different results on further cointegration analysis.

Brenner, R. J., & Kroner, K. F. (1995). Arbitrage, cointegration, and testing the unbiasedness hypothesis in financial markets. Journal of Financial and Quantitative Analysis, 30, 23–42.
Covey, T., & Bessler, D. A. (1992). Testing for Granger's full causality. Review of Economics and Statistics, 74, 146–153.
Covey, T., & Bessler, D. A. (1995). Asset storability and the information content of intertemporal prices. Journal of Empirical Finance, 2, 103–115.
Crain, S. J., & Lee, J. H. (1996). Volatility in wheat spot and futures markets, 1950–1993. Government farm programs, seasonality, and causality. Journal of Finance, 51, 325–343.
Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. Journal of the American Statistical Association, 74, 427–431.
Dickey, D. A., & Fuller, W. A. (1981). The likelihood ratio statistics for autoregressive time series with a unit root. Econometrica, 49, 1057–1072.
Engle, R. F., & Granger, C. W. J. (1987). Cointegration, and error correction. Representation, estimation and testing. Econometrica, 55, 251–276.
Engle, R. F., & Yoo, B. S. (1987). Forecasting and testing in co-integrated systems. Journal of Econometrics, 35, 143–159.
Fortenbery, T. R., & Zapata, H. O. (1993). An examination of cointegration relations between futures and local grain markets. Journal of Futures Markets, 13, 921–932.
Fortenbery, T. R., & Zapata, H. O. (1997). An evaluation of price linkages between futures and cash markets for cheddar cheese. Journal of Futures Markets, 17, 279–301.
Garbade, K. D., & Silber, W. L. (1983). Price movements and price discovery in futures and cash markets. Review of Economics and Statistics, 65, 289–297.
Gardner, B. L. (1976). Futures prices in supply analysis. American Journal of Agricultural Economics, 58, 81–84.
Ghosh, A. (1995) The hedging effectiveness of ECU futures contracts. Forecasting evidence from an error correction model. Financial Review, 30, 567–581.
Ghosh, A., & Clayton, R. (1996). Hedging with international stock index futures. An intertemporal error correction model. Journal of Financial Research, 19, 477–491.
Gonzalo, J. (1994). Five alternative methods of estimating long-run equilibrium relationships. Journal of Econometrics, 60, 203–233.
Hamilton, J. D. (1992). Was the deflation during the great depression anticipated? Evidence from the commodity futures markets. American Economic Review, 82, 157–178.
Holthausen, D. M. (1979). Hedging and the competitive firm under price uncertainty. American Economic Review, 69, 989–995.
Johansen, S. (1991). Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. Econometrica, 59, 1551–1580.
Johansen, S. (1992). Determination of cointegration rank in the presence of a linear trend. Oxford Bulletin of Economics and Statistics, 54, 383–397.

Johansen, S., & Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration-with application to the demand for money. Oxford Bulletin of Economics and Statistics, 52, 169–210.

Kamara, A. (1982). Issues in futures markets. A survey. Journal of Futures Markets, 2, 261–294.

Kroner, K. F., & Sultan, J. (1993). Time-varying distributions and dynamic hedging with foreign currency futures. Journal of Financial and Quantitative Analysis, 28, 535–551.

Lee, T., & Tse, Y. (1996). Cointegration tests with conditional heteroscedasticity. Journal of Econometrics, 73, 401–410.

LeSage, J. P. (1990). A comparison of the forecasting ability of ECM and VAR models. Review of Economics and Statistics, 72, 664–671.

Leuthold, R. (1974). The price performance on the futures market of a nonstorable commodity. American Journal of Agricultural Economics, 56, 271–136.

Lien, D. (1996). The effect of the cointegration relationship on futures hedging. A note. Journal of Futures Markets, 16, 773–780.

Lien, D., & Lou, X. (1994). Multiperiod hedging in the presence of conditional heteroscedasticity. Journal of Futures Markets, 14, 927–955.

Lin, J., & Tsay, R. S. (1996). Co-integration constraint and forecasting. An empirical examination. Journal of Applied Econometrics, 11, 519–538.

Nerlove, M., & Bessler, D. A. (2001). Expectation, information and dynamics. In B. L. Gardner & G. C. Rausser (Eds.), Handbook of agricultural economics: Vol. 1. Amsterdam: Elsevier Science, forthcoming.

Pantula, S. G., Gonzalez-Farias, G., & Fuller, W. A. (1994). A comparison of unit-root test criteria. Journal of Business and Economic Statistics, 12, 449–459.

Peck, A. E. (1985). The economic role of traditional commodity futures markets. In A. E. Peck (Ed.), Futures markets: Their economic roles. Washington, DC: American Enterprise Institute for Public Policy Research, 1–81.

Phillips, P., & Perron, P. (1988). Testing for a unit root in time series regression. Biometrica, 75, 335–346.

Purcell, W. D., & Hudson, M. A. (1985). The economic roles and implications of trade in livestock futures. In A. E. Peck (Ed.), Futures markets: Regulatory issues. Washington, DC: American Enterprise Institute for Public Policy Research, 329–376.

Quan, J. (1992). Two-step testing procedure for price discovery role of futures prices. Journal of Futures Markets, 12, 139–149.

Sabuhoro, J. B., & Larue, B. (1997). The market efficiency hypothesis. The case of coffee and coca futures. Agricultural Economics, 16, 171–184.

Schroeder, T. C., & Goodwin, B. K. (1991). Price discovery and cointegration for live hogs. Journal of Futures Markets, 11, 685–696.

Schwartz, T. V., & Szakmary, A. C. (1994). Price discovery in petroleum markets. Arbitrage, cointegration, and the time interval of analysis. Journal of Futures Markets, 14, 147–167.

Shonkwiler, J. S., & Maddala, G. S. (1985). Modeling expectations of bounded prices: An application to the market for corn. Review of Economics and Statistics, 67, 697–702.

Shumway, C. R., Smith, E. G., & Richardson, J. W. (1995). Impact of target prices and payment limits on the supply function. Review of Agricultural Economics, 17, 185–191.

Skadberg, J. M., & Futrell, G. A. (1966). An economic appraisal of futures trading in livestock. Journal of Farm Economics, 48, 1485–1489.

Stein, J. L. (1981). Speculative price. Economic welfare and the idiot of chance. Review of Economics and Statistics, 63, 223–232.

Working, H. (1948). Theory of the inverse carrying charge in futures markets. Journal of Farm Economics, 30, 1–28.

Yang, J., & Leatham, D. J. (1999). Price discovery in wheat futures markets. Journal of Agricultural and Applied Economics, 31, 359–370.

Zapata, H. O., & Fortenbery, T. R. (1996). Stochastic interest rates and prices discovery in selected commodity markets. Review of Agricultural Economics, 18, 643–654.

Zapata, H. O., & Rambaldi, A. N. (1997). Monte Carlo evidence on cointegration and causation. Oxford Bulletin of Economics and Statistics, 59, 285–298.