

# HOW RELIABLE ARE HOG FUTURES AS FORECASTS?

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The Chicago Mercantile Exchange hog futures contract was revamped in 1997 and it is one of the largest futures markets for a nonstorable commodity. The literature is divided on whether or not futures prices for nonstorables provide reliable forecasts of cash prices. We find that from 1998 to 2004, the hog futures market was an unbiased predictor of cash prices.

*Key words:* nonstorable futures, lean hog futures, futures efficiency.

*Assuming markets are efficient, it does not seem possible to judge, based purely on conceptual models, whether markets for livestock are more likely to provide more- or less accurate forecasts than those for grain markets. This question must be answered empirically.*

-Tomek 1997, p. 42.

For storable commodities like corn, the futures market is viewed as a reliable indicator of how forthcoming cash prices will unfold. However, for nonstorable commodities like hogs, the “forecast power” of futures markets is thought to be low, notwithstanding the above quote from Tomek (Skadberg and Futrell 1966; Kamara 1982; Garbade and Silber 1983; Purcell and Hudson 1985; French 1986). The storage activity links futures and cash prices through the cost of carry, but if inventories do not play a role, as in the case of a nonstorable commodity, then the link between futures and cash prices is broken. Stylized theoretical commodity models predict that the forecasting performance of nonstorable futures prices, measured by a regression  $R^2$ , is zero (Williams 2001).

The Chicago Mercantile Exchange (CME) lean hog futures market is a major nonstorable commodity futures market. A recent study by Boessen et al. (2004) indicates that a large fraction of the U.S. hog industry uses the hog futures market for hedging purposes and that the futures market is central to the hog industry. The U.S. hog industry has undergone dramatic changes in its size, ownership structure, and the way in which prices are discovered, creating new challenges for industry par-

ticipants (Lawrence, Schroeder, and Hayenga 2001). Since the early 1980s, there has been an accelerating trend toward consolidation and vertical coordination in hog production and processing (Barkema, Drabenstott, and Novack 2001). The industry now comprises fewer and larger producers, with production and processing vertically integrated through contracts designed to mitigate risk and facilitate optimal capacity utilization (Haley 2004). Given the evolution in the structure of the U.S. hog industry, the CME futures market has taken an even more prominent role. For instance, coordinated production by large and more specialized producers has led to increasing use of long-term contracts, with the price tied to CME futures. A recent study found that the share of hogs sold to processors under contract was about 80% in 2001, up from about 65% in 1999 (Barkema, Drabenstott, and Novack 2001).

In general, agricultural producers, processors, and other industry participants look to futures prices to form price expectations and to aid in decision making (Gardner 1976; Holthausen 1979; Schroeder and Goodwin 1991). If the futures forecast power is low, then decision making based on such forecasts will be adversely affected. The forecasting performance of hog futures and the ability of the futures market to provide producers and other industry participants with appropriate price signals is therefore a key issue in the industry.

Despite several attempts in the literature to study whether hog futures prices are an unbiased and accurate forecast of cash prices, the empirical evidence remains unclear and somewhat confusing. And to some extent, past studies are outdated given the consolidation in the industry and the restructuring of the hog futures contract (Barkema, Drabenstott, and Novack 2001). For instance, the most recent study on this issue by Yang, Bessler, and

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Leatham (2001) using data from 1996 to 1998 found that hog futures prices were not the primary informational source for cash prices for the 1992 to 1996 time period. However, for the 1996 to 1998 time period, Yang, Bessler, and Leatham found that the futures market was an important informational source for the cash market. The Yang, Bessler, and Leatham findings for the 1996 to 1998 time period are consistent with an earlier study by Fama and French (1987) who used data prior to the early 1980s. Schroeder and Dhuyvetter (1999), using data from 1975 to 1998, found that hog futures prices thirty-six weeks prior to contract expiration provided an unbiased forecast but the forecasting performance, measured by the  $R^2$  of the forecast regression, was low (0.12).

Given the discrepancy in the literature as to whether the CME hog futures price is unbiased or accurate as a cash price forecast and the extent to which the forecast power may have changed over time, this article seeks to further explore the issue. A reexamination of this question is especially opportune in light of a recent structural change in the hog futures market. Beginning in 1997, the lean hog futures contract replaced the live hog futures contract at the CME. Unlike the previous contract, the new lean hog contract is cash settled based on a U.S. Department of Agriculture (USDA)-computed daily price index and does not include terminal market prices, reflecting the rise of both horizontal and vertical integration in the hog industry. The price index is a weighted average of the price paid by packers to hog producers.

The new futures contract more accurately represents the industry's move toward carcass-based pricing where the price of hogs is related to lean meat content rather than live weight (Ditsch and Leuthold 1996). These changes have important implications for the properties of the hogs futures market including its effectiveness as a price discovery instrument. One such difference has been noted by Ditsch and Leuthold (1996) who argued that the lean hog futures should perform significantly better as a hedging instrument compared to the previous live hog futures contract.

In this article we examine the forecasting ability of the CME lean hog futures market by examining the following four fundamental questions<sup>1</sup> (a) do futures prices share a

long-term equilibrium relationship with cash prices? (b) are futures prices an unbiased forecast of cash prices? (c) are futures prices the primary informational source of price discovery—that is, do futures prices lead cash prices in the short and long run? and (d) do futures prices aggregate public information rapidly so there are no profit opportunities available from incorporating information beyond what is contained in futures prices?

Our primary empirical method utilizes an error-correction cointegration framework and formal hypothesis tests to quantify the temporal links between hog futures and cash prices. Using a similar approach, Bessler and Covey (1991) studied U.S. cattle markets and found weak evidence of cointegration between cash and nearby futures prices. Schroeder and Goodwin (1991) failed to find cointegration between cash and futures prices for U.S. live hogs. In contrast, Fortenbery and Zapata (1993) examined markets for storable commodities (corn and soybeans) and found evidence of cointegration in some crop years.

The rest of the article is organized as follows: the second section provides an overview summary of the lean hog futures market and briefly outlines the structural changes that have occurred in the hog market over the past two decades. The third section details our methods and testable hypotheses. The fourth section discusses the results and the final section concludes.

### Lean Hog Futures

The CME lean hog futures contract shares all the common characteristics of a nonstorable commodity futures contract. Each hog contract is based on 40,000 pounds of lean hog carcasses, the quantity of meat produced from slightly more than 200 hogs. In addition to the futures contracts, options on lean hog futures are also traded on the Chicago Mercantile Exchange (CME).

The CME's hog futures contract is based on a lean weight because most finished hogs are

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current information to determine prices (Tomek 1997). A futures market is termed (weak form) efficient if the current futures price fully reflects all available information in past prices (Fama 1970). In an efficient commodity market, the futures price will be an optimal forecast of the future cash price. Therefore, in its simplest form, the efficient market hypothesis is a test that the futures price is an unbiased predictor of the forthcoming spot price (Taylor 1995). The notion that the futures price is an optimal forecast of the spot price is therefore an implication of the efficient market hypothesis. Thus, many articles on forecasting performance of futures markets have implicitly focused on evaluating the weak form efficiency of futures markets (Tomek 1997; Tomek and Gray 1970; Kofi 1973).

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<sup>1</sup> The literature on futures prices as forecasts is closely related to the literature on the efficient market hypotheses. Forecasting performance relates to the question of how well a market uses

sold based on carcass weight, not live weight. So the lean weight contract is a postslaughter price. This means that the futures contract price can be multiplied by about 0.74 to infer the equivalent live hog price per hundred-weight. 0.74 is an approximation of the live hog weight to the lean carcass weight (i.e., a 250–265 pound live hog yields a dressed carcass of approximately 185–195 pounds).

Trading in lean hog futures takes place for eight different contract months: February, April, May, June, July, August, October, and December.<sup>2</sup> Each hog futures contract expires on the tenth business day of the contract (i.e., maturity) month. Any contract open at time of expiry is cash settled at the CME Lean Hog Index (what is often referred to as the “CME cash price”).<sup>3</sup>

The CME Lean Hog Index (CME cash price) is based on a sample of cash and formula price transactions at packinghouses, and is a two-day weighted average of these prices. The prices are provided by cooperating packers located within the Mid-South, Eastern Corn Belt, and Western Corn Belt areas, as reported by the USDA.<sup>4</sup> In the hog futures market there is a daily price move limit of two cents per pound above or below the previous day’s settlement price, with no limits in the delivery month during the last two days of trading.

In 2005, the annual volume of trading in lean hog futures on the CME exceeded four million contracts. This is equivalent to 80 billion pounds of lean hogs, or about eight times the annual production of pork in the United States. The volume of trading in CME lean hog futures surged in the past few years and has doubled since the contract was revamped in 1997.

The supply of hogs slaughtered in any given week or month depends on decisions made by hog producers several months earlier. Sows are generally bred twice per year. From the time a hog producer decides whether to breed sows and gilts it takes about ten months to get pigs to market. This includes time for breeding, gestation, and feeding to finish. The gestation period is three and a half months and the time from birth to slaughter is about six months. Hogs are

slaughtered when they weigh 250–265 pounds, producing a dressed carcass weight of around 185–195 pounds.

So biology dictates that there is limited scope for the hog farmer to affect the timing of when his product is brought to market. The supply of slaughter hogs in any given week was determined at least ten months previous and is perfectly inelastic with respect to the market price of slaughter hogs that week.<sup>5</sup> For this reason the forecast power of the futures market is particularly important in the hog industry. Hogs are sold for slaughter within a rather narrow weight and age span. Once they reach market weight, producers cannot easily hold these animals back from the market. Because hogs are a nonstorable commodity, the cash price is determined by current supply and demand.

## Methods

A basic model for evaluating the forecasting ability of futures markets focuses primarily on the unbiasedness property of futures prices. The most common form of this test is a simple regression model of the equilibrium relationship between futures and cash prices (Bigman, Goldfarb, and Schechtman 1983; Martin and Garcia 1981; Tomek and Gray 1970; Kofi 1973):

$$(1) \quad C_t = \beta_0 + \beta_1 F_{t-i} + \xi_t$$

where  $C_t$  is the cash price at time  $t$  when the futures contract matures,  $F_{t-i}$  is the futures price quotation for contract  $t$ ,  $i$  months before maturity, and  $\xi_t$  is an error term. Futures markets are considered efficient if the futures price is an unbiased forecast of the forthcoming cash price, that is, if  $\beta_0$  and  $\beta_1$  are estimated to be zero and unity, respectively. The  $R^2$  from equation (1) is the percentage of variation in the cash price explained by the futures price and is an indication of forecast power.

Using this approach, most studies have found evidence supporting the notion that nonstorable livestock futures produce biased forecasts of cash prices (Leuthold 1974; Leuthold and Hartman 1979). However, despite its intuitive appeal, this simple regression approach is considered inappropriate and hypotheses tests such as  $t$ - and  $F$ - tests are invalid if cash and futures price series are

<sup>2</sup> The May contract for lean hog futures is fairly new. This maturity month was not included in the analysis because the May contract did not trade for the entire period of study, 1998–2004. May futures trading only started in 2001 for 2002 delivery. Moreover, the trading volume of this contract is relatively thin compared to the other contracts.

<sup>3</sup> The CME also trades futures and options contracts on frozen pork bellies (i.e., bacon) and the contract size is 40,000 pounds. The contract for frozen pork bellies is physically deliverable.

<sup>4</sup> See <http://www.cme.com/trading/prd/ag/lhindex3423.html>

<sup>5</sup> The time-lag issue and the short-run inelasticity of supply are emphasized by Bullock (2003).

nonstationary (Elam and Dixon 1988; Brenner and Kroner 1995).

With nonstationary prices, cointegration theory (Engle and Granger 1987; Johansen 1988; 1991) provides a more comprehensive approach by taking into account both the long- and the short-run behavior of futures and cash prices. A convenient representation of cointegrated behavior that separates out the short-term adjustment component and the long-term equilibrium component is the error-correction model (ECM) (Johansen, 1988; Hendry, 1995).<sup>6</sup>

Using cointegration theory the ECM for hog cash and futures price series can be written as:

$$(2) \quad \Delta P_t = \delta_0 + \delta_1 t + \sum_{i=1}^{p-1} A_i^* \Delta P_{t-i} + \alpha(\beta' P_{t-1} + \beta_0 + \beta_1 t) + e_t.$$

In equation 2,  $\Delta$  is a difference operator,  $P_t$  is a  $2 \times 1$  vector of dependent variables (cash and futures prices), and  $\delta_0$  and  $\delta_1$  are  $2 \times 1$  vectors of coefficients for intercept and linear time-trend terms, in differenced cash and futures prices. Each  $A_i^*$  represents a  $2 \times 2$  matrix of coefficients on lagged differenced cash and futures prices. Cointegration relations are represented by the  $2 \times r$  matrices,  $\alpha$  and  $\beta$ , where  $r$  denotes the number of cointegrating relations in the system. Coefficients of intercept and linear time-trend terms in the levels of cash and futures prices are represented by the  $2 \times 1$  vectors,  $\beta_0$  and  $\beta_1$ . Finally,  $e_t$  denotes a  $2 \times 1$  vector of mutually orthogonal random price disturbances, assumed to be serially uncorrelated with zero mean and constant variance.

The short-run dynamics of the system are governed by the matrix of lagged coefficients,  $A_i^*$ . The coefficients in  $\alpha$  and  $\beta$  (error-correction terms) represent the long-run components of the model. Given that cash and futures prices have a long-run relationship,  $\beta$  contains the cointegrating vectors or long-run equilibria of the cash and futures prices, and  $\alpha$  contains the error-correction coefficients that determine the speed of adjustment toward long-run equilibrium following a short-run de-

viation. The closer the coefficients of  $\alpha$  are to zero, the longer it takes for the series to revert to their long-run trend after a shock.

Our primary objective here is to estimate the equilibrium relationship specified in equation 1 within the ECM framework of equation 2. The specification includes a constant term in the equilibrium relationship. We, therefore, include a constant term ( $\beta_0$ ) in the cointegration relationship in all estimations of the ECM. In addition, the general form of equation 2 allows us to include a linear trend in the equilibrium relationship, through restrictions on the parameters  $\beta_1$ ,  $\delta_0$ , and  $\delta_1$  (Hendry 1995).

The error-correction specification is estimated using the method of Johansen (1990), which involves simultaneous estimation of the ECM and the cointegrating relationship by maximum likelihood methods. The Johansen method also allows hypothesis testing on the coefficients of  $\alpha$  and  $\beta$  through the use of likelihood ratio tests (Johansen and Juselius 1990).

Using the ECM specification, the efficiency of futures prices as forecasts can be evaluated using four testable hypotheses. The first hypothesis (cointegration hypothesis) is whether cash and futures prices share a long-run relationship, that is, whether they are cointegrated (Beck 1994; Fortenbery and Zapata 1997; Lai and Lai 1991; Antoniou and Foster 1994). Intuitively, if the price series are not cointegrated they will drift apart in the long run and this result would be inconsistent with the notion that futures prices can predict cash prices.

Cointegration implies reduced rank restrictions on the error-correction term; if the two series are cointegrated, then  $\text{rank}(\alpha\beta') = r < n$ , where  $n$  is the number of price series being modeled (Johansen 1988).<sup>7</sup> The Johansen cointegration test exploits this property. Cointegration can be tested by checking the rank of the long-run matrix, that is, by determining  $\text{rank}(\alpha\beta') = r$ ,  $r = 0$ ,  $r = 1, \dots, r = n$ .

We use Johansen's (1992) sequential likelihood ratio test procedure to determine if including a trend term in the cointegration relationship is appropriate. The approach jointly considers the determination of the number of cointegration relations,  $r$ , in the system as well as the trend specification to be used. For

<sup>6</sup> Several articles have used cointegration analysis to model commodity prices. These studies 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; Sabuhoro and Larue 1997; Quan 1992 and Schwartz and Szarmay, 1994. According to these studies, there is substantive evidence of cointegration between cash and futures prices for storable commodities. However, for nonstorable commodities there is little or no evidence of cointegration between cash and futures prices.

<sup>7</sup> In equation 2, if the two price series ( $P$ ) are each nonstationary and  $I(1)$ , and  $\Delta P$  is stationary, then  $\alpha\beta'P_{t-1}$  has to be  $I(0)$ . This implies a rank condition on the matrix  $\alpha\beta'$ . To determine the number of cointegrating relations we proceed sequentially from  $r = 0$  to  $r = k - 1$  until we fail to reject the null hypotheses. A zero rank implies no cointegration, and a rank of one implies that the two variables are cointegrated.

instance, consider the following hypotheses regarding the number of cointegrating relations in the system:  $r = 0, r = 1, \dots, r = n$ . Johansen's sequential approach requires testing each of the  $n$  hypotheses regarding the number of cointegration relationships sequentially using both the restricted model (without trend) and the unrestricted model (with trend), starting with the restricted model. At the first instance in which we fail to reject the null hypothesis, we stop testing and accept the number of cointegrating relations suggested by the test as well as the trend specification used in the test.

A second necessary condition for the efficiency of futures forecasts is that futures prices should be unbiased forecasts of cash prices. This condition can be examined by evaluating the coefficients of the long-run matrix,  $\beta$ . If the price series are cointegrated, futures prices are unbiased forecasts of forthcoming cash prices only if there exist coefficients such that  $C_t - \alpha - \beta F_{t-i} = v_t$  is a stationary process. If this restriction is not rejected, then there is evidence supporting the hypothesis that in the long run the equilibrium cash price is equal to the futures price and a constant. Thus, our second hypotheses test of whether futures prices are unbiased forecasts is whether  $\beta' = (1, -1)$ .

The above tests will measure the long-run relationship between cash and futures prices. However, they do not identify which series leads the relationship and which follows. For futures prices to be efficient and accurate predictors of cash prices, it is necessary that futures prices lead cash prices in the long run. To test this property, we turn to the statistical concept of weak exogeneity. A series is regarded as weakly exogenous if it leads other series in the long run without being influenced by other series. The weakly exogenous series, therefore, can be used as a predictor or explanatory variable for explaining variations in the "nonexogenous" series (Zapata and Rambaldi 1997; Yang, Bessler, Leatham 2001). Using this statistical concept, our third hypothesis is that futures prices are weakly exogenous with respect to cash prices (weak exogeneity hypothesis). We test the hypothesis by examining the error-correction coefficients,  $\alpha$ . If one of the series has a zero error-correction coefficient (that is, its corresponding element in  $\alpha$  is zero) the series is regarded as weakly exogenous and as the leader of the equilibrium relationship.

However, short-run inefficiencies may be present if lagged cash and futures prices (through the parameters  $A_j^*$ ) help explain movements in the cash price (Fackler and

Goodwin 1999). To correctly determine if futures prices lead cash prices we must account for lags in cash and futures prices. This means that taken together, our third hypothesis test of interest (short-run efficiency hypothesis) is to evaluate if  $A_j^* = 0$  for each series  $j$ .

The final requirement for the efficiency of hog futures prices is that all information is aggregated into futures prices and there is no leftover information. This proposition implies that there is no serial correlation in the residuals of the ECM. Serial correlation signals that futures prices do not aggregate all information as quickly as possible and forecasting performance could therefore be improved by incorporating the information in the residuals (Hansen and Hodrick 1980; Bilson 1981; Liu and Madalla 1992).

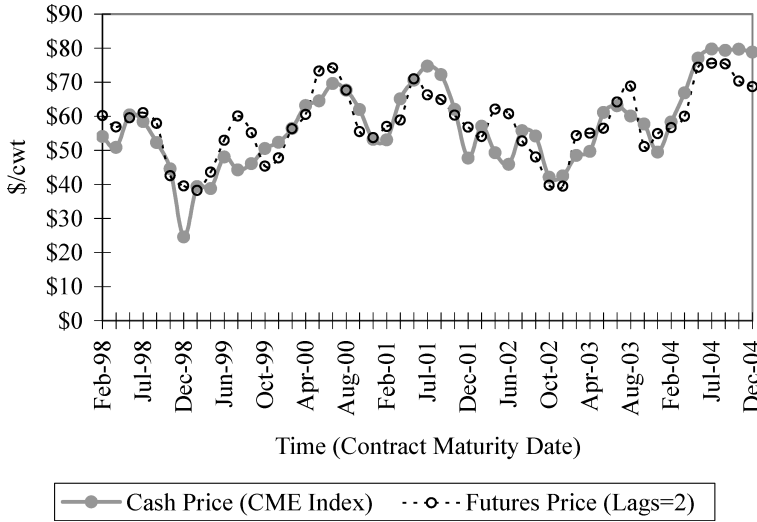
## Results

We begin with a descriptive analysis of the relationship implied by equation 1 using data on futures and cash prices for the 1998 to 2004 time period. The cash prices used are the CME cash price indexes for the first day of the relevant maturity month, obtained from the CME. The futures prices are for the maturity months of February, April, June, July, August, October, and December each year, obtained from the *Commodity Research Bureau* in Chicago.<sup>8</sup> For the forecast of the cash price we use the closing futures price on the first business day in the lagged month.

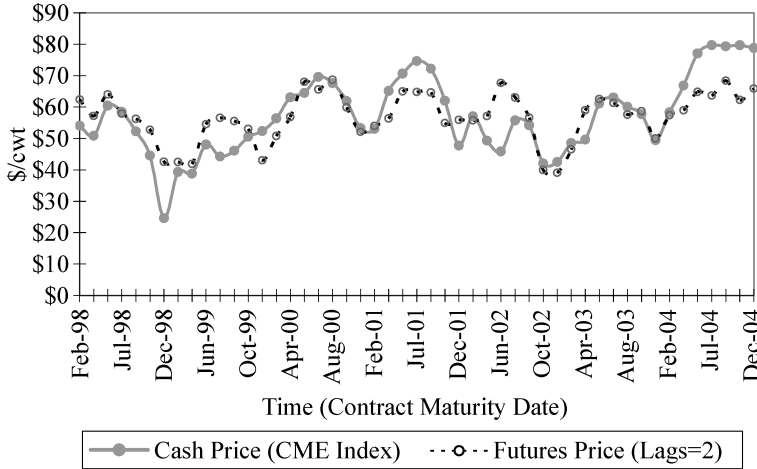
Figures 1 through 4 show lean hog futures prices as a forecast of maturity month cash prices. The futures maturity month actual cash price ( $C_t$ ) is plotted as a solid circle in each figure. For each cash price, the earlier futures market forecast ( $F_{t-i}$ ) of that price is plotted as a hollow circle, directly above or below the solid circle representing the cash price. The figures displays futures market forecasts two, four, six, and ten months prior to the realized cash price.

Visual inspection of these four figures indicates that hog futures prices are a reasonable forecast of maturity month cash prices for two-, four-, and six-month lagged futures prices. For figures 1 through 3, the vertical gap between the forecast and the realized cash price is relatively small. The average size of the gap widens as we move from figure 1 through to figure 4. For the two-month ahead forecast, the average

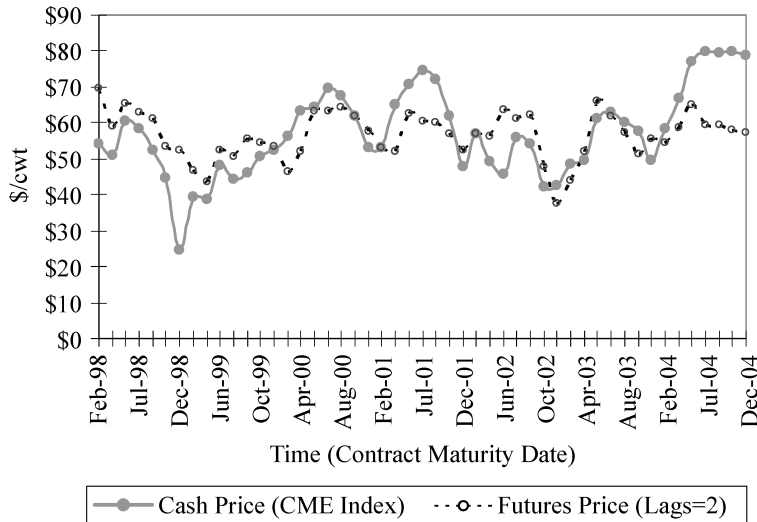
<sup>8</sup> See [www.crbtrader.com](http://www.crbtrader.com)



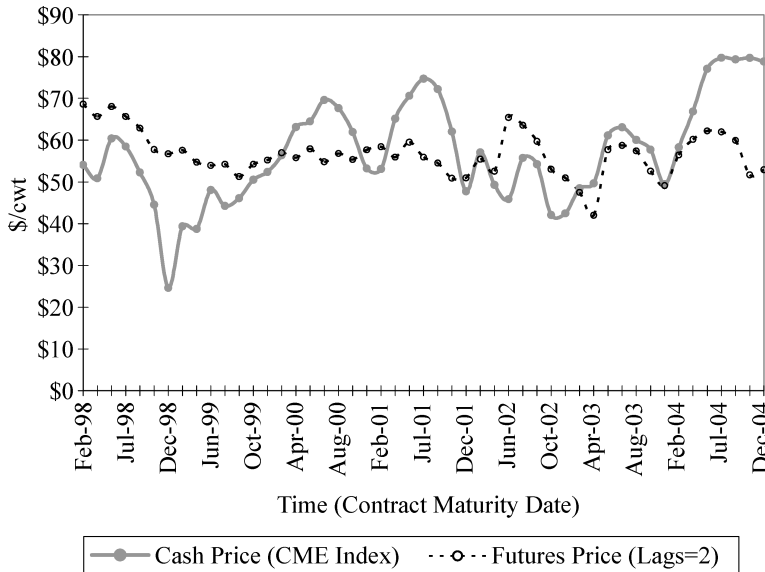
**Figure 1. Lean hogs: Maturity month cash price and two-month lagged futures price, 1998–2004**



**Figure 2. Lean hogs: Maturity month cash price and four-month lagged futures price, 1998–2004**



**Figure 3. Lean hogs: Maturity month cash price and six-month lagged futures price, 1998–2004**



**Figure 4. Lean hogs: Maturity month cash price and ten-month lagged futures price, 1998–2004**

of the absolute value of the forecast error was \$5.42/cwt. The average forecast error (in absolute value) increased to \$6.32, \$8.05, and \$9.91 for the four-, six-, and ten-month ahead forecasts. This simple descriptive statistic suggests that hog futures prices approximate the forthcoming cash price quite well, although the accuracy of forecasts declines for more distant prices because less information is aggregated by distant prices.

A stronger sense of the forecast power of hog futures prices can be obtained by more formally testing the unbiasedness of futures prices using the framework in equation (1) and assuming both price series are stationary. As indicated earlier, if futures prices are unbiased forecasts of cash prices then the estimated values for  $\beta_0$  and  $\beta_1$  should be zero and unity. In table 1 (columns 1 to 4) the estimated slope coefficients lie close to the value of unity while the intercepts in most models are statistically insignificant. We test these hypotheses using individual and joint  $F$ -tests and find that for the two-, four-, and six-month futures forecasting models, the regression slope coefficients are not statistically different from one, and the intercept estimates are not statistically different from zero (table 1, columns 1 to 4, bottom panel). So the hog futures market provides a good forecast of cash prices six months out. However, for forecasts ten months away, the regression slope coefficient is different from one and the intercept is different from zero—suggesting that future forecasts ten months out are biased (downward).

The  $R^2$  for the two-, four-, six-, and ten-month ahead forecasts are 0.70, 0.56, 0.28, and 0.03 (table 1, bottom panel). This indicates that the forecast power declines the more distant the forecast (as we would expect), but even the six-month ahead forecast has reasonably good explanatory power. However, the forecast power breaks down if we ask the futures market to forecast cash prices ten months out.<sup>9</sup>

For comparison purposes we performed similar tests of forecasting power using cash prices instead of futures prices as forecasts (table 1, columns 5 to 8). The forecasts of current cash prices generated from the lagged cash prices are strikingly inferior to the forecasts using lagged futures prices. Current cash prices for hogs are biased forecasts of forthcoming cash prices (i.e.,  $\beta_1 \neq 1$ ). The  $R^2$  of the cash forecast model even two months out is quite low. A formal test of the forecasting performance of the two alternative forecasting models using the Diebold-Mariano mean squared error (MSE) test confirms that futures prices provide much better forecasts than cash prices (table 1, bottom panel).<sup>10</sup>

<sup>9</sup> For each of the four forecasting models in Table 1, additional specifications using a dummy variable to represent falling and rising price regimes were estimated. The results are not reported here, but they were qualitatively equivalent to the results shown in Table 1.

<sup>10</sup> Given the actual series of realized cash prices we calculate a measure of predictive accuracy of the two alternative models, using a mean squared error (MSE) criterion. The MSE criterion also allows a formal test of the null hypothesis of equal accuracy of cash and futures prices in forecasting forthcoming cash prices. For each of the four models the MSE criterion and corresponding tests of

**Table 1. Forecasting Models of Cash Prices Using Futures Prices**

	Futures Price model: $C_t = \beta_0 + \beta_1 F_{t-i} + \xi_t$				Cash Price Model: $C_t = \beta_0 + \beta_1 C_{t-i} + \xi_t$			
	(2 months)	(4 months)	(6 months)	(10 months)	(2 months)	(4 months)	(6 months)	(10 months)
$\beta_0$	-2.61 (5.79)	-9.48 (8.69)	1.51 (12.97)	35.36 (18.97)*	21.55 (7.43)**	44.06 (10.10)***	47.55 (8.42)***	55.70 (8.77)***
$\beta_1$	1.03 (0.09)***	1.16 (0.15)***	0.984 (0.22)***	0.38 (0.33)	0.63 (0.12)***	0.23 (0.17)	0.193 (0.15)	-0.49 (0.16)**
$R^2$	0.70	0.56	0.28	0.03	0.34	0.24	0.05	0.00
Hypotheses (F) Tests								
$H_0: \beta_1 = 1$	Fail to reject	Fail to reject	Fail to reject	Reject	Reject	Reject	Reject	Reject
$H_0: \beta_0 = 0$	Fail to reject	Fail to reject	Fail to reject	Reject	Reject	Reject	Reject	Reject
$H_0: \beta_0 = 0, \beta_1 = 1$	Fail to reject	Fail to reject	Fail to reject	Fail to reject	Reject	Reject	Reject	Reject
Diebold-Mariano Test								
$H_0: MSE_F = MSE_C$	2.09***	2.08***	2.34***	1.18				

Note: Standard errors are reported in parentheses. Asterisk (\*), double asterisk (\*\*), and triple asterisk (\*\*\*) denote significance at 10%, 5%, and 1%, respectively. The null hypothesis for the Diebold test is  $H_0: MSE \text{ of futures forecast} \leq MSE \text{ of the cash forecast}$ . *F*-tests for the latter test are conducted at significance levels of 10% or less.

**Table 2. Tests for Unit Roots in Hog Cash and Futures Price Series**

Test	Deterministic Terms	Transformation	Test Statistic	
			Cash Price	Futures Price
ADF	Constant	Levels	-2.48	-2.49
		Differenced	-14.83**	-19.80**
	Constant and time-trend	Levels	-2.99	-3.02
		Differenced	-14.83**	-19.80**
Phillips-Perron	Constant	Levels	-2.39	-2.51
		Differenced	14.52**	-42.60**
	Constant and time-trend	Levels	-2.91	-3.06
		Differenced	-14.53**	-42.63**

Note: Table entries are Augmented Dickey-Fuller and Phillips-Perron test statistics. Asterisk (\*) and double asterisk (\*\*) denote variables significant at 5% and 1%, respectively.

To evaluate the validity of the results in table 1, we examine the nonstationarity properties of the data. We test the null hypothesis of stationary using Augmented Dickey Fuller (ADF) and Phillips Perron tests. The results of our stationarity tests indicate that both price series in levels contain unit roots but the first difference of each variable is stationary (table 2). This is true across both models—with and without a trend. Since the tests differ in the manner in which they account for serial correlation in the data (the Phillips Perron test uses Newey-West standard errors to account for serial correlation while the augmented Dickey-Fuller test uses additional lags of the first-difference variable) the use of both methods provides a more robust result. Based on the results in table 2 we conclude that each price series is integrated of order one and its first difference is stationary.

Given that the data are nonstationary, we now analyze the efficiency of hog futures within a cointegration framework. Specifically, we test the four hypotheses stated above. Fol-

lowing our empirical approach outlined in the previous section we estimate an ECM both with and without a linear trend in the price series and test for the presence of cointegration between cash and futures prices. In all cases we include a constant term in the ECM specification to be consistent with the equilibrium model in equation 1. The Akaike Information and Final Prediction error criteria were used to determine the optimal order of lags (eight lags for each series). The Trace statistics indicate that for both the with-trend and without-trend specification we can reject the null hypothesis of no cointegrating vector ( $r = 0$ ) in favor of one cointegrating vector ( $r = 1$ ) at the 5% level of significance (table 3). Further, under sequential testing, the first rejection failure occurs while using the model without trend and, thus, we accept the model without trend as appropriate.<sup>11</sup> Taken together, the Johansen procedure strongly supports the existence of cointegration and we conclude that there is

statistical significance shows that futures forecasts are significantly better than cash forecasts.

<sup>11</sup> We also used the sequential procedure to evaluate if other combinations of the trend specification (as shown in Osterwald-Lenum 1992), were appropriate. The results of these tests did not alter our current choice of specification.



**Table 3. Test for Cointegration Between Hog Cash and Futures Prices**

	$H_0: \text{rank}(\alpha\beta') = r$	Trace test statistic	5 % Critical Value
Model without trend	$r = 0$	48.97	19.96
	$r = 1$	6.79*	9.24
Model with trend	$r = 0$	53.33	25.32
	$r = 1$	10.58*	12.25

Note: Critical values are from Osterwald-Lenum (1992). Asterisk (\*) indicates failure to reject a null hypothesis. The value of  $r$  reported is the number of cointegrating relations identified by Johansen's Trace test procedure.

**Table 4. Estimated Cointegrating Vectors and Adjustment Coefficients for Hog Futures and Cash Price ECM**

	ECM
Cointegrating Vector ( $\beta$ )	
$\beta_{\text{Cash}}$	1
$\beta_{\text{Futures}}$	-1.105 (0.066)**
Constant	6.458 (3.861)
Adjustment coefficient ( $\alpha$ )	
$\alpha_{\text{Cash}}$	-0.0130 (0.002)**
$\alpha_{\text{Futures}}$	-0.0015 (0.006)

Note: Standard errors are shown in parentheses for parameters. Asterisk (\*) and double asterisk (\*\*) denote variables significant at 5% and 1%, respectively.

a long-run relationship between hog futures and cash prices.

The normalized cointegrating vectors and speed of adjustment toward equilibrium are reported in table 4. The cointegrating coefficient on the futures price series is estimated to be close to 1 and significantly different from zero in both specifications of the ECM model, suggesting that futures prices are unbiased. Note that the Johansen method imposes a normalization on one of the series; here the normalization is on the cash series. The adjustment coefficients for futures and cash prices are estimated as  $-0.001$  and  $-0.01$ , respectively. These magnitudes imply that the burden of price adjustment following a short-run shock to equilibrium falls primarily on the cash market. When futures prices are relatively high, the cash price adjusts so that the two converge in the long run. The small magnitude of the coefficient suggests, however, that the process of adjustment is slow.

Given the existence of cointegration between futures and cash prices, formal testing of the unbiasedness hypotheses was conducted using a Likelihood ratio test of the restriction

$\beta' = (1, -1)$ . The test statistic, which follows a  $\chi^2$  distribution, fails to reject the null hypotheses of unbiasedness of futures forecasts (table 5). This result suggests that hog futures prices are the most accurate forecasts of expected forthcoming cash prices, and market participants can rely on the futures price to accurately predict the cash price over long forecasting horizons.

We test the weak exogeneity hypotheses using the likelihood ratio test with a  $\chi^2$  distributed test statistic (Johansen 1991). We conduct several versions of the test on each price series by combining the weak exogeneity test with the unbiasedness test for both ECM models. The null hypothesis that cash prices are weakly exogenous for the long-run equilibrium relationship is strongly rejected, at the 1% level (table 5). Weak exogeneity is not rejected for the futures price series, indicating that futures prices are not affected by short-run interruptions of equilibrium. Rather, it is cash prices that adjust to bring back the market equilibrium. If there is a large positive departure from the long-run equilibrium between hog futures and cash prices in the current period, it is corrected in the next period by an adjustment in the cash market. In contrast, cash prices do not affect futures prices. This finding is consistent with an efficient market in which futures prices lead cash prices. The results are consistent in both individual and joint tests of the hypothesis. Taken together, the results indicate that hog futures prices are unbiased and they lead the behavior of cash prices in the short- and long-run price discovery process.

We test the short-run forecasting efficiency of futures prices by imposing restrictions on the lagged explanatory variable coefficients of each price series. The null hypotheses that the lagged cash price differenced terms in the futures equation are jointly zero cannot be rejected. The hypothesis that lagged futures price differenced terms in the cash equation are jointly zero is strongly rejected at the 1% level of significance. This finding has two important

**Table 5. Hypotheses Tests for Efficiency of Hog Futures Market**

Hypotheses		LR Test Statistic ( <i>P</i> -Value)
$H_0: \beta' = (1, -1)$	Unbiasedness	2.145 (0.143)
$H_0: \alpha_{\text{cash}}$	Weak exogeneity of cash	35.32 (0.00)**
$H_0: \alpha_{\text{futures}} = 0$	Weak exogeneity of futures	0.049 (0.824)
$H_0: \beta' = (1, -1), \alpha_{\text{futures}} = 0$	Weak exogeneity, unbiasedness	2.90 (0.234)
$H_0: A_{f,c}^* = 0$	SR causality from cash to futures	125.82 (0.00)**
$H_0: A_{c,f}^* = 0$	SR causality from futures to cash	3.95 (0.818)
$H_0: \rho = 0$	No serial correlation	2.009 (0.416)

Note: *p*-values are reported in parenthesis. Asterisk (\*) and double asterisk (\*\*) denote variables significant at 5% and 1%, respectively. The likelihood ratio test statistic for the restrictions has a  $\chi^2$  distribution with the degrees of freedom equal to the number of restrictions.

implications. First, it shows that in the short-run futures prices lead movements in cash prices but there is no reverse feedback from cash prices. Second, the significance of lagged futures price terms in the cash equation reveals that despite the long-run efficiency of futures prices as forecasts of cash prices, there is some inefficiency in the short run. The long-run efficiency is also supported by testing for the hypothesis of no serial correlation in the residuals of the ECM. Using a Lagrange Multiplier test we find no evidence of serial correlation in the residuals (table 5).

### Conclusion

In a 1997 essay, Bill Tomek argued that if we assume futures markets are efficient, then we cannot a priori determine whether markets for livestock commodities provide accurate cash price forecasts, relative to the market for storable commodities. Others such as French (1986) and Williams (2001) have implied that the forecast power is low for non-storable futures markets. But it is really an empirical question. In this article we investigate the forecast power and efficiency of the CME lean hog futures market. The hog futures contract was restructured in 1997 and trading volume since then has risen sharply. Given the rapid consolidation in the U.S. hog industry, price formation in the futures market has taken a more prominent role with the growth in vertical integration, long-term contracting, and formula pricing. Our empirical results show that the CME futures market is the primary price discovery point for hogs and that the futures

market is a good and unbiased predictor of forthcoming cash prices except for very distant contracts.

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### References

- Antonioni, A., and A.J. Foster. 1994. "Short-Term and Long-Term Efficiency in Commodity Spot and Futures Markets." *Financial Markets, Institutions & Instruments* 3:17–35.
- Baille, R.T., and R.J. Myers. 1991. "Bivariate Garch Estimation of the Optimal Commodity Futures Hedge." *Journal of Applied Econometrics* 6:109–24.
- Barkema, A., M. Drabenstott, and N. Novack. 2001. "The New U.S. Meat Industry." *Economic Review* 2:33–56.
- Beck, S. E. 1994. "Cointegration and Market Efficiency in Commodity Futures Markets." *Applied Economics* 26:249–57.
- Bessler, D.A., and T. Covey. 1991. "Cointegration. Some Results on U.S. Cattle Prices." *Journal of Futures Markets* 11:461–74.
- Bigman, D., D. Goldfarb, and E. Schechtman. 1983. "Futures Market Efficiency and the Time Content of the Information Sets." *Journal of Futures Markets* 3:321–34.
- Bilson, J.F.O. 1981. "The Speculative Efficiency Hypothesis." *Journal of Business* 54:435–51.
- Boessen, C., J. Lawrence, and G. Grimes. 2004. "Production and Marketing Characteristics of US Pork Producers." Working Paper, Department of Economics, Iowa State University.

- Brenner, R.J., and K.F. Kroner. 1995. "Arbitrage, Cointegration, and Testing the Unbiasedness Hypothesis in Financial Markets." *Journal of Financial and Quantitative Analysis* 30:23–42.
- Bullock, J.B. 2003. "Performance Evaluation of the U.S. Hog Slaughter Industry." Working Paper, Department of Agricultural Economics No. AEWP 2003-1, University of Missouri-Columbia.
- Covey, T., and D.A. Bessler. 1995. "Asset Storability and the Information Content of Intertemporal Prices." *Journal of Empirical Finance* 2:103–15.
- Ditsch, M., and R. Leuthold. 1996. "Evaluating the Hedging Potential of the Lean Hog Futures Contract." OFOR Paper Number 96-03, Office for Options and Futures Research, University of Illinois at Urbana-Champaign.
- Elam, E., and B.L. Dixon. 1988. "Examining the Validity of a Test of Futures Market Efficiency." *Journal of Futures Markets* 8:365–72.
- Engle, R.F., and C.W.J. Granger. 1987. "Cointegration and Error Correction: Representation, Estimation, and Testing." *Econometrica* 55:251–76.
- Fackler, P.L., and B.K. Goodwin. 1999. "Spatial Price Analysis." Forthcoming. *Handbook of Agricultural Economics*. Amsterdam: North-Holland Press.
- Fama, E.F. 1970. "Efficient Capital Markets: A Review of Theory and Empirical Work." *The Journal of Finance* 25:383–417.
- Fama, E., and K. French. 1987. "Commodity Futures Prices: Some Evidence on Forecast Power, Premiums and the Theory of Storage." *Journal of Business* 60:55–73.
- Fortenbery, T.R., and H.O. Zapata. 1993. "An Examination of Cointegration Relations Between Futures and Local Grain Markets." *Journal of Futures Markets* 13:921–32.
- Fortenbery, T.R., and H.O. Zapata. 1997. "An Evaluation of Price Linkages Between Futures and Cash Markets for Cheddar Cheese." *Journal of Futures Markets* 17:279–301.
- French, K.R. 1986. "Detecting Spot Price Forecasts in Futures Prices." *Journal of Business* 59:39–54.
- Garbade, K.D., and W.L. Silber. 1983. "Price Movements and Price Discovery in Futures and Cash Markets." *Review of Economics and Statistics* 65:289–97.
- Gardner, B.L. 1976. "Futures Prices in Supply Analysis." *American Journal of Agricultural Economics* 58:81–84.
- Haley, M. 2004. "Market Integration in the North American Hog Industries." Outlook Report No. LDPM12501. USDA, Economic Research Service, November 2004 available at: [www.ers.usda.gov/publications/ldp/nov04/ldpm12501/](http://www.ers.usda.gov/publications/ldp/nov04/ldpm12501/).
- Hansen, L.P., and R.J. Hodrick. 1980. "Forward Exchange Rates as Optimal Predictors of Future Spot Rates: An Econometric Analysis." *Journal of Political Economy* 88:829–53.
- Hendry, D.F. 1995. *Dynamic Econometrics*. Oxford: Oxford University Press.
- Holthausen, D.M. 1979. "Hedging and the Competitive Firm Under Price Uncertainty." *American Economic Review* 69:989–95.
- Johansen, S. 1988. "Statistical Analysis of Cointegration Vectors." *Journal of Economic Dynamics and Control* 12:231–54.
- Johansen, S. 1990. "The Power Function for the Likelihood Ratio Test for Cointegration." Institute of Mathematical Statistics, University of Copenhagen.
- Johansen, S. 1991. "Estimation and Hypothesis Testing of Cointegrating Vectors in Gaussian Vector Autoregressive Models." *Econometrica* 59:1551–80.
- Johansen, S., and K. Juselius. 1990. "Maximum Likelihood Estimation and Inference on Cointegration—With Applications 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 Market* 2:261–94.
- Kofi, T. 1973. "A Framework for Comparing the Efficiency of Futures Markets." *American Journal of Agricultural Economics* 55:584–94.
- Lai, K.S., and M. Lai. 1991. "A Cointegration Test for Market Efficiency." *Journal of Futures Markets* 11:567–75.
- Lawrence, J.D., T.C. Schroeder, and M.L. Hayenga. 2001. "Evolving Producer–Packer–Customer Linkages in the Beef and Pork Industries." *Review of Agricultural Economics* 23(2):370–85.
- Leuthold, R.M. 1974. "The Price Performance on the Futures Markets of a Nonstorable Commodity: Live Beef Cattle." *American Journal of Agricultural Economics* 55:271–9.
- Leuthold, R.M., and P.A. Hartmann. 1979. "A Semi-Strong Form Evaluation of the Efficiency of the Hog Futures Market." *American Journal of Agricultural Economics* 61:482–9.
- Liu, P.C., and G.S. Maddala. 1992. "Rationality of Survey Data and Tests for Market Efficiency in the Foreign Exchange Markets." *Journal of International Money and Finance* 11:366–81.
- Martin, L., and P. Garcia. 1981. "The Price-Forecasting Performance of Futures Markets for Live Cattle and Hogs: A Disaggregated Analysis." *American Journal of Agricultural Economics* 63:209–15.

- Osterwald-Lenum, M. 1992. "A Note With Fractiles of the Asymptotic Distribution of the Maximum Likelihood Cointegration Rank Test Statistics: Four Cases." *Oxford Bulletin of Economics and Statistics* 54:461-72.
- Purcell, W.D., and M.A. Hudson. 1985. "The Economic Roles and Implications of Trade in Live-stock Futures." In A.E. Peck, ed. *Futures Markets: Regulatory Issues*, pp. 329-376. Washington: American Enterprise Institute for Public Policy Research.
- Quan, J. 1992. "Two-Step Testing Procedure for Price Discovery Role of Futures Prices." *Journal of Futures Markets* 12:139-49.
- Sabuhoro, J.B., and B. Larue. 1997. "The Market Efficiency Hypothesis. The Case of Coffee and Coca Futures." *Agricultural Economics* 16:171-84.
- Schwartz, T.V., and A.C. Szakmary. 1994. "Price Discovery in Petroleum Markets. Arbitrage, Cointegration, and the Time Interval of Analysis." *Journal of Futures Markets* 14:147-67.
- Schroeder, S.T., and K. Dhuyvetter. 1999. "Forecasting Performance of Storable and Non-Storable Commodities." NCR-134 Proceedings, pp. 317-33.
- Schroeder, T.C., and B.K. Goodwin. 1991. "Price Discovery and Cointegration for Live Hogs." *Journal of Futures Markets* 11:685-96.
- Skadberg, J.M., and G.A. Futrell. 1966. "An Economic Appraisal of Futures Trading in Live-stock." *Journal of Farm Economics* 48:1485-9.
- Taylor, M.P. 1995. "The Economics of Exchange Rates." *Journal of Economic Literature* 33:13-47.
- Tomek, W.G. 1997. "Commodity Futures Prices as Forecasts." *Review of Agricultural Economics* 19:23-44.
- Tomek, W.G., and R.W. Gray. 1970. "Temporal Relationships Among Prices on Commodity Futures Markets: Their Allocative and Stabilizing Roles." *American Journal of Agricultural Economics* 48:372-80.
- Williams, Jeffrey. 2001. "Commodity Futures and Options." In Bruce L. Gardner, and Gordon C. Rausser eds. *Vol. II of Handbook of Agricultural Economics*. North-Holland: Amsterdam, pp.745-816.
- Yang, J., D.A. Bessler, and D.J. Leatham. 2001. "Asset Storability and Price Discovery in Commodity Futures Markets: A New Look." *Journal of Futures Markets* 21:279-300.
- Zapata, H.O., and T.R. Fortenbery. 1996. "Stochastic Interest Rates and Prices Discovery in Selected Commodity Markets." *Review of Agricultural Economics* 18:643-54.
- Zapata, H.O., and A.N. Rambaldi. 1997. "Monte Carlo Evidence on Cointegration and Causation." *Oxford Bulletin of Economics and Statistics* 59:285-98.