LIVESTOCK FUTURES MARKETS AND RATIONAL PRICE FORMATION: EVIDENCE FOR LIVE CATTLE AND LIVE HOGS

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Abstract

The efficiency of livestock futures markets continues to receive attention, particularly with regard to their forward pricing or forecasting ability. The purpose of this paper is to present a more general theory that encompasses the forward pricing concept. It is argued that futures contract prices for competitively produced nonstorable commodities, such as live cattle and live hogs, follow a rational formation process. Futures contract prices reflect expected market conditions when contracts are sufficiently close to the delivery month that the supply of the underlying commodity cannot be changed. However, prior to the period when future supplies are relatively fixed, futures contract prices should adjust to reflect the competitive equilibrium, where output price equals average costs of production. Presented evidence suggests that live cattle and live hog futures markets support the rational price formation hypothesis: prices for distant contracts reflect average costs of feeding. Implications for risk management strategies are considered.

Key words: futures markets, rational price formation, forecasting performance, forward pricing

In recent years, the efficiency of livestock futures markets has received increased attention. Responding to producer concerns that futures markets are detrimental to the industry, researchers have examined the roles of livestock futures markets in discovering and forecasting prices, allocating resources to production, and registering market information (Purcell and Hudson). The results of these studies are mixed and often depend on the time period and method of analysis (Garcia et al. 1988a). The available research suggests difficulties in drawing definitive conclusions about the efficiency of livestock futures markets.

Two roles of futures markets have been emphasized in analyses of market performance (Tomek and Gray; Peck 1985 and 1987). The first role, the allocative role, was investigated initially by Working in a study of grain basis relationships and storage costs. The availability of futures contracts for storable commodities, deliverable upon out to a year in the future, are thought to provide price incentives which influence storage decisions and thereby allocate grain consumption through the crop year. Analysis of the second role, forward pricing, emerged with the introduction of futures trading in semi-storable commodities (e.g., onions and potatoes) and nonstorable commodities (e.g., livestock). It has been argued that price levels of futures contracts for nonstorable commodities, deliverable upon out to a year in the future, should forecast anticipated supply-demand conditions in these forward markets. Futures markets for semi-storable commodities are thought to combine these two roles.

A dilemma has emerged in the literature in that futures markets for storable commodities perform both the allocative and forward pricing roles well, while futures markets for nonstorable commodities are typically poor forecasters (Leuthold and Hartmann; Just and Rausser; Martin and Garcia; Shonkwiler). The conclusion often drawn is that the futures markets for nonstorable commodities are inefficient, that the speculators in these markets are not using all available information, and that *ex ante* welfare losses are incurred by society (Stein).

This paper examines the live cattle and live hog futures markets within the rational pricing framework suggested by Gray. At the outset, it is argued that early in its life a livestock futures contract trades in a price range around average costs of feeding. Early in the contract life is defined as the period when the supply to be marketed during the delivery month can be influenced by the futures prices. Once the possibility of supply response is eliminated through production commitments (e.g., when the

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time to contract expiration is less than the length of the feeding period), then futures prices should adjust to reflect market conditions expected to prevail at contract maturity. Prior to performing this forward pricing or forecasting role, futures contract prices should trade close to average costs of feeding. If they do not, they may elicit producer behavior which will self-defeat the futures price.

The paper is structured as follows. Previous literature related to the forecasting performance of livestock futures markets is briefly reviewed in the next section. In section three, the issue of rational price formation in futures markets is developed, and an empirical test is suggested. The models and data employed in the study are discussed in the fourth section. Section five presents the empirical results of the inquiry. In section six, the implications of the results for hedging strategies are discussed. The paper ends with concluding remarks.

RELEVANT LITERATURE

The standard approach to assessing futures market efficiency assumes that a market is efficient if prices reflect all relevant and available information (Fama). Arguments are then made that if futures markets for nonstorable commodities are performing the forward pricing role efficiently, futures prices should be accurate forecasts of subsequent cash prices. The forecasting performance of livestock futures markets has been widely examined within this framework (see Kamara for a review of earlier research), most commonly by comparing the accuracy of price forecasting models to the accuracy of the futures market in predicting subsequent prices (Leuthold; Leuthold and Hartmann; Just and Rausser; Martin and Garcia; Garcia et al. 1988b; Leuthold et al.; Shonkwiler). Results of such analyses typically suggest that futures markets do not satisfy the efficiency criteria in a forecasting context and that the forecasting ability of futures markets deteriorates as the forecast horizon increases.

Interpretation of futures prices as forecasts has been questioned in the literature. Working contends that futures prices are not forecasts and that any futures market cannot be a forecasting agency and a mechanism for rational price formation. However, this argument was made in a paper emphasizing the allocative role of grain futures prices. This may have delayed application of the concept to nonstorable commodities, the area where it may be most useful (Peck 1987). In general, livestock futures prices continue to be interpreted as a consensus of what traders expect the cash price of the underlying commodity to be at contract expiration (Shonkwiler).

Tomek and Gray integrate the allocative and forward pricing roles of futures markets. They suggest that futures markets for all commodities play both roles to some degree and that the storage characteristics of the commodity determine the extent of each role. For storable commodities, the role is primarily allocative, but by influencing storage decisions, futures prices become self-fulfilling forecasts. For semi-storable commodities, the futures market should play an allocative role across the time period that the crop is in storage (within crop year) but a forward pricing role across periods when the crop is not stored (across crop years). For nonstorable commodities, such as livestock, the futures market should play a forward pricing role. The empirical results of Tomek and Gray suggest that for Maine potato futures prices (a semi-storable commodity), the allocative role is satisfied but the forward pricing role is not. They conclude that a simple cobweb model based on historic cash prices provides a better forecast than do futures prices. This characteristic, attributed to pricing inefficiency, persists in literature examining nonstorable commodity futures markets.

Gray later provides some rationalization as to why futures markets for nonstorable commodities are not good forecasters. He suggests that "... production responds to current and recent prices, but if futures were to reflect the anticipation of this response they would necessarily abort it in that reflection" (p. 348). Further, in response to the result that a cobweb model is a better predictor than futures markets, Gray states "... a futures market cannot reflect the backward oriented cobweb mechanism without evoking the responses and hence the prices which will prove that reflection wrong" (p. 343). In other words, if prices for distant futures contracts are good predictors of expected market conditions, they will elicit supply responses by producers, thereby negating the accurate prediction.

The literature on rational price formation, outside of evaluating forecasting performance, is relatively limited. Only Miller and Kenyon (1977) and Purcell et al. attempt to examine the link between futures prices and cost of production in livestock markets. This paper contributes to the literature by more carefully identifying why futures markets for nonstorable commodities are not good forecasters, offering an alternative to the forward pricing role which suggests that futures markets are pricing rationally even if they do not forecast well at certain horizons, and presenting an empirical test for rational price formation illustrated with data from live cattle and live hog markets.

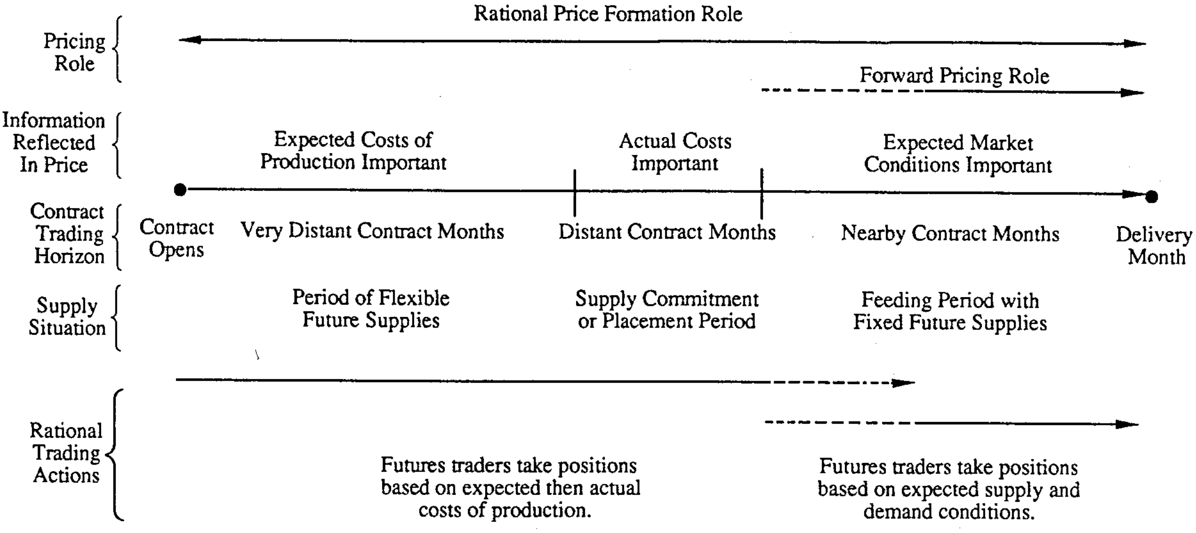

Figure 1. Time Dimensions and Phases of a Futures Contract Life Associated with the Rational Price Formation Concept

RATIONAL PRICE FORMATION

Futures prices are more complex than a price forecast. Futures contracts are used to facilitate merchandising of the underlying commodity, and there is arbitrage between the forecasting agency and agents using the forecast. Arbitrage can be direct through hedging (Working) or indirect through the use of the futures price as an expected output price on which production decisions are based.[1] The implication is that futures contract prices can influence production decisions which in turn affect subsequent contract prices. The result is that the forecast can influence its own realization.

Research on forecasting performance has tended to ignore this arbitrage and the fact that futures prices are the result of trade between two economic agents. A buy and a sell decision takes place with each trade, and trade is voluntary. If the post-trade price changes, one of the two agents must lose money. From a market equilibrium perspective, the cumulative effect of individual incentives should result in a market price that will not elicit direct or indirect arbitrage. Such arbitrage guarantees one of the agents a loss and would be irrational.[2] This appears to be the motivation for Working's original statements about rational price formation. The futures market will not forecast if doing so elicits behavior that will prove the forecast wrong.

The concept of rational price formation is sufficiently general to encompass the forward pricing role (see Figure 1). When a futures contract for a nonstorable commodity is near maturity, the forward pricing role is consistent with rational price formation. Traders in the futures market take positions based on expected market conditions during the delivery month. Futures prices for nearby contracts should reflect underlying supply and demand information as that information becomes available. However, prior to committing animals to feed, rational price formation suggests that the futures prices for distant and very distant contracts should trade around expected and then actual average costs of production (see Figure 1). Rational futures traders should recognize that if price levels are above (below) average costs of feeding prior to commitment of animals to feed, the futures market may elicit an increase (decrease) in supply, and the subsequent futures price will be lower (higher) in the delivery month than current levels. Thus, the futures market should offer producers neither pure profits nor guaranteed losses prior to making feeding commitments.[3] If futures contract prices reflect feeding costs, the futures market is rational because it reflects

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[1] Various analyses of feeding and marketing decisions made by cattle and hog producers suggest that these decisions are influenced by futures prices (Paul and Wesson; Ehrich; Miller and Kenyon 1977 and 1979; Hoffman; Leuthold).

[2] This argument is true for trade among all agents. In trade between two speculators, the idea is straightforward. In trade between a speculator and a hedger, the hedger may expect modest losses across many hedges, payment of a risk premium, but it would be irrational for the hedger consistently to guarantee losses in excess of the risk premium.

[3] Arguments made by Helmuth suggesting that live cattle futures are downward biased because they do not offer pure profits during the placement periods are not correct if rational price formation holds for distant and very distant live cattle contracts.

competitive market equilibrium conditions. This relationship is not covered by the forward pricing role. However, it does appear to be related to the allocative role.

There is a pool of resources available to produce fed animals. The futures market assists in allocating these resources to production through providing price signals when production decisions are made. The futures market should recognize the competitive nature of the feeding industry and, prior to the time when animals can be committed to feed, contracts should be priced at levels comparable to costs expected at the time of commitment (see Figure 1). When the time to maturity of a futures contract is equivalent to the length of the feeding period, the contract should be priced to reflect current actual feeding costs. Further, the futures contract should continue to be priced at current feeding costs for the length of the placement period—as long as a supply response is possible. After producers make feeding commitments, futures prices should mitigate the supply response, if placements are adequate, or encourage continued placements, if commitments are relatively small. In doing so, futures prices will begin to reflect anticipated market conditions. Livestock futures markets should allocate resources to the feeding process by initially pricing future output at levels equivalent to expected and then actual costs of production—recognizing the competitive equilibrium condition. After resources are committed, the futures market then begins to reflect anticipated market conditions at contract expiration. If futures prices in distant contract months reflect costs of production, this would suggest that futures traders have rational expectations. In a competitive industry, where supply commitments continue flexible, output should be priced equal to average costs of production. The use of the competitive market equilibrium condition to formulate expectations about futures prices is an underlying idea of the rational expectations concept (Dewbre).

Three further issues need to be addressed in moving from the conceptual model to empirical tests of rational price formation in live cattle and live hog futures markets. These issues reflect assumptions implicit in the empirical tests of the conceptual model. The assumptions are interrelated and introduced from specific to the most general. First, there are no barriers to entry in cattle and hog feeding. Arguments above suggest that over the life of a contract (one year), imminent fed cattle and hog supplies are initially flexible and then become fixed. This should be true for marginal increases or decreases in numbers of animals on feed. For cattle, flexibility in backgrounding programs suggests that feeder animal supplies are flexible and that it is the commitment to finish the animal that fixes future supplies. With respect to hog feeding, production may be fixed when breeding decisions are made (ten to eleven months prior to marketing) or when pigs are placed on feed (four to six months prior to marketing).

Second, throughout the earlier discussion, the concepts of "committing animals to feed" and "fixing of future supplies" were used interchangeably. In cattle and hog feeding, animals marketed in any one month must have been on feed rations for the prior four to six months in order to achieve marketable weights and quality. Further, once an animal is on feed, there are few economic alternatives other than continuing the feeding process.[4] Fed cattle supplies are arguably fixed once animals are placed on feed (typically four to six months prior to slaughter), although there is some flexibility as to when animals are marketed (plus or minus two weeks from the ideal finish date). Market hog supplies become essentially fixed earlier, sometime between the decision to breed sows (ten to eleven months prior to slaughter of the market hog) and the decision to place pigs on feed (four months prior to slaughter of the market hog). There is less flexibility in slaughter hog marketing. Empirical results should reveal when supplies go from being flexible to fixed by indicating when futures prices no longer move with average feeding costs.

Third, market performance studies typically do not separate the effects on prices of inadequate market information and market inefficiency (Hudson et al.). Research on how futures markets adjust to new information (Miller; Schroeder et al.) and the effects of anticipated versus unanticipated information on price (Colling and Irwin 1989 and 1990) is limited. Because there is a time lag between when feeding commitments are made and when information on production decisions becomes publicly available (i.e., through USDA reports), there may be a lag between when the futures prices reflect feeding costs and when they reflect expected market conditions. (The transition is illustrated by both sets of the overlapping dashed arrows in Figure 1.) For example, hog supplies may be fixed once breeding deci-

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[4] This is supported by USDA figures. Numbers from monthly cattle on feed reports suggest that only 5 to 7 percent of cattle removed from feedlots are not marketed as finished animals. This percentage includes death loss. There is more flexibility with individual animals in hog feeding, in that gilts on feed can be placed in the permanent breeding herd. However, this flexibility is limited in aggregate because the breeding herd is approximately 15 percent of the size of the market hog herd.

sions have been made. However, live hog futures may continue to reflect feeding costs until actual numbers of hogs on feed (i.e., market hogs) are publicly announced via USDA inventory reports. This distinction is related to the second issue; it is important for interpretation of results, and it is a researchable issue. However, it does not affect the conceptualization of rational price formation or the empirical models.

MODELS AND DATA

The test for rational price formation in the live cattle and live hog futures markets used regressions of feeding costs on futures contract prices. Monthly feeding costs were regressed on futures prices at various months from delivery. The basic model was

$$(1)\ FP(t-i)_k = \alpha_0 + \alpha_1\, VC^*(t-j)_k + \varepsilon_{1k}$$

where i and $j = 0,\ldots,11$ denote the months prior to the delivery month t. The observations are over futures contracts and are denoted k. FP(t-i) denotes an average monthly price of contracts expiring in month t with i months remaining for trade. $VC^*(t-j)$ denotes aggregate U.S. variable costs of feeding in month j, which is j months prior to the delivery month t of the futures price dependent variable. The model captures the hypothesized equilibrium relationship between average costs of feeding and futures prices. Short-run competitive equilibrium suggests that prices are related to average variable costs, while long-run equilibrium suggests that prices are related to average total costs. The model represents an intermediate relationship. The intercept will capture the portion of fixed costs reflected in equilibrium prices.[5] There were 12 models involved in the test reflecting futures contract prices over the 12-month horizon for which contracts were traded, $i = 0,\ldots,11$ (j is specified below). The models were treated as a seemingly unrelated regression system.

Variable production costs representative of Great Plains cattle feeding and Corn Belt hog feeding operations were obtained from the USDA ERS *Livestock and Meat Situation and Outlook.* Variable feeding costs were defined to be the feed and feeder animal costs from USDA production budgets converted to dollar per hundredweight of live animal. Great Plains cattle feeding budgets assume that 600 pound feeder steers are purchased and fed 1500 pounds of milo, 1500 pounds of corn, 400 pounds of cotton seed meal, and 800 pounds of alfalfa hay over six months and are sold at 1056 pounds (1100 pounds less 4 percent shrink). Corn Belt hog feeding budgets assume that 40-50 pound feeder pigs are purchased and fed 11 bushels of corn and 130 pounds of protein supplement over five months and are sold at 220 pounds. All feed is assumed to be bought at the time of feeder animal purchase.[6] The monthly Great Plains cattle feeding cost series was available from February 1975 to the present. The monthly Corn Belt hog feeding cost series was available from July 1973 to the present. Futures contracts used in the analysis included all live cattle contracts traded from the February 1975 through the December 1989 contract (excluding the illiquid January contracts), and all live hog contracts traded between their introduction with the June 1974 contract through the December 1989 contract. Averages of daily closing prices were constructed for each contract month and each calendar month across the 12-month trading horizon. The futures data were gathered from *CME Yearbooks* and the *Wall Street Journal.* There were 90 and 110 observations for each of the live cattle and live hog models, respectively.[7]

Evidence suggests that USDA budgets are systematically different from actual feedlot production cost data (Trapp). The difference is due to improvements in technical efficiency (e.g., gains from implants and genetics) and seasonal low cost substitutions by feedlot operators (e.g., varying feeds and types of feeder animals purchased among seasonal low cost alternatives). The difference between USDA variable costs (VC) and aggregate U.S. variable costs (VC*) was approximated with a cubic time trend and series of monthly dummy variables. The expression used to capture aggregate U.S. variable costs was

$$(2)\ VC^*(t-j)_k = \delta_0 + VC(t-j)_k + \sum_{m=1}^{3} \delta_{1m}\, \mathrm{trend}_k^m + \sum_{m=1}^{C-1} \delta_{2m} S_{mk} + \varepsilon_{2k}$$

where S_{mk} denotes seasonal dummies for (all but one of) the futures contracts traded per year, where C is six for cattle and seven for hogs. The trend variable

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[5] The final specification includes a trend variable which should capture possible longer-term changes in fixed costs.

[6] This method should accurately capture costs incurred by commercial feeders. The cost of the feeder animal is 15 to 25 percent of total feeding costs and is incurred at placement. Allocating feed costs at prices observed at placement is appropriate if producers buy feed at placement or if producers hedge expected feed use at placement; grain futures contract prices across contract months are related primarily by storage costs. Thus, feed costs at placement and hedged feed costs are comparable. The practice of hedging total feed use at placement is common among commercial feeders.

[7] There are six live cattle and seven live hog contracts traded per year.

was based on the year and month of expiration and thus captures the irregular temporal spacing of the hog contracts. Substituting equation (2) into the regression (1) and combining parameters and error terms yields the estimable model:

$$(3)\ FP(t-i)_k = \beta_0 + \beta_1 VC(t-j)_k + \sum_{m=1}^{3} \beta_{2m}\, trend_k^m + \sum_{m=1}^{C-1} \beta_{3m} S_{mk} + \varepsilon_k.$$

The model was examined under two alternative specifications of *j* where (*i* = 0,...,11) resulting in two systems of equations. The first system paired futures prices with contemporaneous costs, or *j* = *i*. The second system paired futures prices with incurred costs, or *j* = *i* for *i* greater than the feeding period. When *i* was less than the feeding period, *j* was equal to the number of months in the feeding period. In other words, in the contemporaneous cost system, futures prices in the delivery month were modelled as a function of feeding costs in the delivery month; futures prices one month from delivery were modelled as a function of feeding costs one month from delivery. To complete the system, analogous models were constructed where futures prices two through eleven months from delivery were modelled as a function of feeding costs two through eleven months from delivery. In the incurred costs system, futures prices in the delivery month and all months between the placement and delivery months were modelled as a function of feeding costs during the placement month. To complete the incurred cost system, contemporaneous cost models for futures prices at maturities greater than the length of the feeding period were included.[8] Both of these systems provide evidence about the existence of rational price formation.

The contemporaneous cost system modeled futures prices as a function of actual costs over three trading horizons identified in Figure 1. The focus of the system was on the link between costs and futures prices during the placement period. Futures prices should move with costs during this period. Further, in the nearby contract trading horizon, the models should identify when the relationship between futures prices and costs deteriorates. This illustrates when the market views future supplies as fixed, or at least when information on future supplies becomes known. This is the time period when traders should begin to take positions based on expected market conditions. Models in the very distant contract trading horizon approximate expected costs with current actual costs. This potential limitation was recognized. However, time series properties of the cost data suggested that this approximation was appropriate. After trend and seasonality were accounted for, autocorrelations and partial autocorrelations suggested that the monthly cost series were essentially random. Thus, the best forecast for costs one to 12 months ahead was the current actual cost level (given that the models incorporate trends and seasonality). Further, the potential limitation was lessened in that conclusions about rational price formation were made cautiously with evidence from these very distant contract month models.

The incurred cost system provided additional evidence about the presence of rational price formation. This system should highlight the linkage between futures prices and costs early in the contract life and the deterioration of the relationship as futures contracts mature. Correlations of error terms in the system will also illustrate whether futures contracts are priced so that self-defeating supply responses occur. Positive errors in the models imply that futures prices are at a premium to costs and that negative errors imply a discount. Negative correlations between placement period model errors and delivery month model errors imply that premiums (discounts) during the placement period trigger behavior by livestock feeders that results in discounts (premiums) during the delivery month.

The necessary condition for rational price formation in both systems is that the estimated coefficient on the cost variable is insignificantly different from one ($\beta_1 = 1$) in models where the time to maturity of the futures price variable is greater than the length of the feeding period. That is, futures prices should reflect costs in periods where supply decisions are flexible. However, if rational price formation links futures prices to costs early in the contract life, and if, after the placement period, futures prices symmetrically move above and below costs in the sample of data, then the estimated cost coefficient may continue to be insignificantly different from one in some nearby contract models. In other words, even if the relationship between futures prices and costs is deteriorating, the tying of futures prices to costs early in trading and to symmetric price adjustments after the placement period may result in the appearance that prices continue to move with costs during the

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[8] For the contemporaneous costs models *i* = *j* = 0,...,11. For the incurred costs models *j* = 5 if *i* = 0,...,4. That is, futures prices less than five months from delivery were modelled as a function of costs incurred five months prior to delivery. The process of determining this specification is discussed later. The specified systems are shown in Tables 1 and 2.

nearby months. Thus, a sufficient condition is needed to verify rational price formation where the slope estimate suggests that futures move with feeding costs, but that this relationship is actually deteriorating relative to the relationship in the placement period. The sufficient condition is that the variance of the estimated cost coefficient and the error variance should be smallest for models of futures prices prior to and during the placement period.

To summarize, if futures prices reflect feeding costs over the trading horizon when supply is not fixed, then the estimated cost coefficient should be insignificantly different from one, and the error variance should be small. Once feeding commitments are made and information on these commitments becomes available, the futures should reflect expected market conditions and will not necessarily mirror cost changes. This implies that the cost coefficient is not necessarily equal to one and that the estimated cost coefficient variances and error variances should increase significantly in models of contracts closer to maturity.

EMPIRICAL RESULTS

Lagrange multiplier tests conducted on least squares residuals of the two systems suggested that cross equation correlation was persistent in both and that seemingly unrelated regressions were appropriate (Breusch and Pagan). Error diagnostics also suggested that a majority of the models in the two systems exhibited first-order serial correlation (Kiviet).[9] The results that follow are from models estimated via iterative seemingly unrelated regressions corrected for first-order serial correlation. Initial estimates of the models using least squares and a seemingly unrelated system identified the model of futures prices five months from delivery as the model with the smallest error variance. Thus, the specification of i and j in the incurred cost system (equation 3) for both cattle and hogs was: $j = 5$ for $i = 0,...,5$ and $j = i$ for $i = 6,...,11$.[10] As a whole, results supported the rational price formation hypothesis as an explanation for price behavior of distant live cattle and live hog futures contracts.

Live Cattle Futures

Table 1 presents a portion of the live cattle results. To conserve space, parametric results for the seasonal dummy variables are not presented (see Koontz et al. for the complete results). Parameter estimates for the seasonal dummies were as expected, suggesting significant seasonal variations in variable costs of feeding not captured by the USDA budgets. The polynomial trend variables were not included in the final specification of the live cattle systems. Error variances of the models in the seemingly unrelated system with trend variables were larger than those of models with only the seasonal factors.

The regression results linking feeding costs to live cattle futures prices over various times to contract maturity were supportive of rational price formation in the distant contract months. Table 1 presents the cost variable coefficient β_1, the autoregressive error parameter ρ, model R-square, and model root error variance σ. In the contemporaneous cost models, the estimated cost coefficients were insignificantly different from one from the delivery month model through the model of prices seven months from delivery. The cost coefficient was significantly different from one at the 10 percent level in the eight and nine month models and at the 5 percent level in the10 and 11 month models. The coefficients were smaller than one in these cases, suggesting that futures do not adjust fully to cost changes in the very distant months or that current actual costs do not fully approximate future expected costs. Most importantly, futures prices move very closely with costs during the placement period. Estimates of the cost coefficients (and their standard errors) four, five, and six months prior to contract expiration were 1.0127 (0.0235), 1.0180 (0.0223), and 0.9907 (0.0316).

The cost coefficient standard errors and root error variances declined as the time to contract maturity increased from the delivery month to five months prior to delivery and remain fairly constant thereafter. The root error variance was \$3.43/cwt. for the delivery month model and decreased to \$2.04/cwt. for the model of prices five months from delivery.

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[9] Higher order autoregressive or moving average patterns were not observed in the errors. The irregular temporal spacing of the hog futures contracts also suggested that a more complex error process was likely. If an autoregressive process of order one is observed between the bimonthly observations, the monthly observations between the June, July, and August contracts should exhibit an autoregressive moving average process, both of order one, where the parameters of the two processes are algebraically related to the original autoregressive term and there is but one free parameter (Harvey). However, including the more complex error process in the systems of equations to capture a different structure between the bimonthly and monthly observations did not yield any statistical improvements. The simpler system with autoregressive errors of order one across all observations had some of the best statistical properties, and the findings were qualitatively identical to those of the more complex specification. The simpler specification is therefore reported.

[10] The model with the smallest error variance may not be $j = 5$ after iteratively estimating the autocorrelated system; however, this lag length must be specified before estimation.

Table 1. Regression Results Explaining Live Cattle Futures Prices with Variable Costs of Feeding, February 1975 through December 1989

Dependent Variable	Independent Variable	β_1	ρ	R^2	σ	t-test 1[a]	t-test 2[b]
			Contemporaneous Cost Models				
FP(t)	VC(t)	1.0576	0.4368**	0.8946	3.4314	———	1.8054
		(0.0674)[c]	(0.0777)[c]				(0.0373)[c]
FP(t-1)	VC(t-1)	1.0539	0.2516**	0.9228	2.8695	-0.8260	3.2909
		(0.0428)	(0.0765)			(0.2056)[d]	(0.0007)
FP(t-2)	VC(t-2)	1.0298	0.5197**	0.9316	2.6791	-0.9371	1.2531
		(0.0546)	(0.0757)			(0.1758)	(0.1069)
FP(t-3)	VC(t-3)	1.0200	0.4404**	0.9556	2.1552	-1.4973	0.2181
		(0.0407)	(0.0746)			(0.0691)	(0.4139)
FP(t-4)	VC(t-4)	1.0127	-0.0369	0.9521	2.2161	-1.5218	0.4875
		(0.0235)	(0.0745)			(0.0660)	(0.3136)
FP(t-5)	VC(t-5)	1.0180	-0.0051	0.9600	2.0359	-1.8054	———
		(0.0223)	(0.0728)			(0.0374)	
FP(t-6)	VC(t-6)	0.9907	0.2901**	0.9587	2.0262	-1.7140	-0.0254
		(0.0316)	(0.0804)			(0.0452)	(0.5101)
FP(t-7)	VC(t-7)	0.9819	0.3473**	0.9675	1.8311	-1.8352	-0.4015
		(0.0291)	(0.0708)			(0.0351)	(0.6554)
FP(t-8)	VC(t-8)	0.9599†	0.1583**	0.9606	1.9733	-1.6815	-0.1273
		(0.0251)	(0.0707)			(0.0483)	(0.5505)
FP(t-9)	VC(t-9)	0.9595†	0.1222*	0.9543	2.1790	-1.5277	0.3575
		(0.0261)	(0.0683)			(0.0653)	(0.3575)
FP(t-10)	VC(t-10)	0.9418††	0.2420**	0.9611	1.9746	-1.7311	-0.1355
		(0.0284)	(0.0715)			(0.0436)	(0.5537)
FP(t-11)	VC(t-11)	0.9213	0.4043**	0.9607	2.0090	-1.6828	-0.0555
		(0.0370)	(0.0795)			(0.0482)	(0.5220)
			Incurred Cost Models				
FP(t)	VC(t-5)	-0.3550††	0.9549**	0.8185	4.5039	——	2.3963
		(0.1854)[c]	(0.0359)[c]				(0.0094)[d]
FP(t-1)	VC(t-5)	0.1513††	0.8863**	0.8491	4.0121	-0.5907	5.6407
		(0.1681)	(0.0504)			(0.2782)[d]	(0.0001)
FP(t-2)	VC(t-5)	0.9029††	0.2119**	0.8404	4.0928	-0.4216	4.0497
		(0.0575)	(0.0660)			(0.3372)	(0.0001)
FP(t-3)	VC(t-5)	0.9845	0.1129	0.9080	3.1001	-1.3962	2.5243
		(0.0411)	(0.0714)			(0.0833)	(0.0068)
FP(t-4)	VC(t-5)	0.9984	0.3011**	0.9406	2.4675	-1.9635	1.2708
		(0.0404)	(0.0823)			(0.0265)	(0.1037)
FP(t-5)	VC(t-5)	1.0234	0.1308	0.9650	1.9065	-2.3963	——
		(0.0250)	(0.0843)			(0.0094)	
FP(t-6)	VC(t-6)	0.9883	0.2912**	0.9587	2.0262	-2.2764	0.3106
		(0.0328)	(0.0824)			(0.0127)	(0.3785)
FP(t-7)	VC(t-7)	0.9943	0.3069**	0.9670	1.8448	-2.3716	-0.1334
		(0.0293)	(0.0752)			(0.0101)	(0.5529)
FP(t-8)	VC(t-8)	0.9776	0.1096**	0.9598	1.9942	-2.2463	0.1894
		(0.0246)	(0.0714)			(0.0137)	(0.4251)
FP(t-9)	VC(t-9)	0.9775	0.0317	0.9512	2.2523	-2.0843	0.8422
		(0.0254)	(0.0711)			(0.0202)	(0.2011)
FP(t-10)	VC(t-10)	0.9622†	0.1779**	0.9598	2.0068	-2.2827	0.2375
		(0.0269)	(0.0700)			(0.0126)	(0.4064)
FP(t-11)	VC(t-11)	0.9460†	0.3403**	0.9600	2.0264	-2.3041	0.2835
		(0.0339)	(0.0782)			(0.0119)	(0.3888)

†† and † denote significantly different from one at the 5 and 10 percent levels, respectively.

** and * denote significantly different from zero at the 5 and 10 percent levels, respectively.

[a] Statistic for the one-tailed test of whether or not the error varianve of the model with FP(t) as the dependent variable is *greater* than the error variance of the remaining models.

[b] Statistic for the one-tailed test of whether or not the error variance of the model with FP(t-5) as the dependent variable is *smaller* than the error variance of the remaining models.

[c] Standard errors are in parentheses under parameter estimates.

[d] P-values are in parentheses under test stastics and denote the probability of rejecting the null hypothesis when the null is true.

Table 1 also presents two t-statistics which test whether the error variance of the delivery month model ($i = 0$) was greater than the error variance for each of the other models (t-test 1),

(4) $H_{Ai} : \sigma_0^2 < \sigma_i^2$ for $i = 1,\ldots 11$,

and whether the error variance of the model five months from delivery ($i = 5$) was less than the error variance for each of the other models (t-test 2),

(5) $H_{Ai} : \sigma_5^2 < \sigma_i^2$ for $i = 0,\ldots,4\ 6,\ldots,11$.

Usually, testing the difference between variances involves an F-statistic. However, this test requires independence of the underlying random variables. Model errors within systems are dependent random variables. Therefore, the t-test outlined in Cox and Hinkley (pp. 140-1) was used.

The values of t-test 1 for the contemporaneous cost models indicated that the error variances of the more distant month models were significantly smaller than the variance of the delivery month model. Error variances of the futures price models one and two months from delivery were smaller than the delivery month model error variance but not significantly smaller. Error variances of models at the three, four, and nine month horizons were significantly smaller at the 10 percent level. The remaining error variances, including that for the five month model, were all significantly smaller than the delivery month model error variance at the 5 percent level. The values of t-test 2 indicated that most of the error variances in the contemporaneous cost system were not significantly different from the error variance of the model of futures five months from delivery. However, the error variances of the models of prices one month from delivery and during the delivery month were significantly greater at the 5 percent level.

The incurred cost system displayed results similar to those of the contemporaneous cost system. The only difference is that, as expected, the cost coefficients during the delivery and a nearby month were significantly different from one. One month prior, and during the delivery month, futures prices were unrelated to actual costs incurred five months prior. The root error variance was $4.50/cwt. for the delivery month model and decreased to $1.91/cwt. for the model of prices five months from delivery. The t-statistics for the incurred cost system revealed a pattern almost identical to that of the contemporaneous cost system. The error variance was smallest for the model of futures prices five months prior to delivery and largest for the model of prices during the delivery month.

The estimated cost coefficients, their standard errors, and the t-tests of the relative error variance sizes all supported rational price formation in the distant contract months. Futures prices consistently moved with costs of feeding from seven months prior to delivery until the delivery month. However, this relationship began to deteriorate two months from delivery and had severely deteriorated one month from and during the delivery month. Up until two months prior to the delivery month, futures continued to reflect incurred costs of feeding. Between two months prior to and the delivery month, futures moved with costs, but in a less systematic fashion. During the delivery month, the standard error and the root error variance were the largest of any of the months over the trading horizon.

Live Hog Futures

As with the live cattle model results, results for the live hog futures models supported rational price formation, although they were somewhat less conclusive. Table 2 presents a portion of the findings, with the trend and seasonal results excluded. The trend and seasonal results were as expected. Feeding costs exhibited a trend that was declining at a decreasing rate and seasonal variations that were not captured in the USDA budgets.

The estimated cost coefficients β_1, autoregressive error parameters ρ, R-squares, and root error variance σ for the contemporaneous cost models are presented in Table 2. In the contemporaneous cost system, most of the cost coefficients were significantly different from one. However, the cost coefficient in the model of futures prices seven months from delivery was not significantly different from one at the 10 percent level, and the cost coefficients in the five and eight months from delivery models were not significantly different from one at the 5 percent level. Most importantly, during the feeding commitment month, the fifth month prior to delivery, the cost coefficient was 1.0448 with a standard error of 0.0567. Futures moved with costs very closely during this period. The root error variance of the models was largest in the nearby and most distant months. The smallest root error variance was in the fifth month model. This suggests that futures were most influenced by costs during the month when animals were committed to the feeding process. However, in the very distant contract month model, actual costs may not have approximated expected future costs well.

Table 2 also reports t-statistics examining the difference between the variance of the delivery month model and other error variances (t-test 1) and the difference between the variance of the five months from delivery model and other models (t-test 2). As

Table 2. Regression Results Explaining Live Hog Futures Prices with Variable Costs of Feeding, June 1974 through December 1989

Dependent Variable	Independent Variable	β_1	ρ	R^2	σ	t-test 1[a]	t-test 2[b]
			Contemporaneous Cost Models				
FP(t)	VC(t)	1.3164††	0.3554**	0.7869	3.3895	——	1.7703
		(0.1081)[c]	(0.0814)[c]				(0.0398)[d]
FP(t-1)	VC(t-1)	1.3099††	-0.1653*	0.7690	3.5046	0.2012	5.5695
		(0.0670)	(0.0857)			(0.5795)[d]	(0.0001)
FP(t-2)	VC(t-2)	1.3700††	-0.1383	0.8689	2.6960	-1.0472	1.3492
		(0.0534)	(0.0871)			(0.1487)	(0.0901)
FP(t-3)	VC(t-3)	1.1816††	0.0278	0.8844	2.3745	-1.4028	0.4438
		(0.0504)	(0.0760)			(0.0818)	(0.3290)
FP(t-4)	VC(t-4)	1.2627††	-0.0113	0.8725	2.5339	-1.2184	0.9402
		(0.0562)	(0.0829)			(0.1129)	(0.1746)
FP(t-5)	VC(t-5)	1.0448	0.2523**	0.8833	2.2002	-1.7703	——
		(0.0567)	(0.0722)			(0.0398)	
FP(t-6)	VC(t-6)	1.1641††	-0.1679**	0.7935	3.0945	-0.3911	1.8001
		(0.0511)	(0.0794)			(0.3483)	(0.0374)
FP(t-7)	VC(t-7)	1.0596†	-0.3245**	0.6847	3.5991	0.2537	2.1388
		(0.0440)	(0.0647)			(0.5999)	(0.0174)
FP(t-8)	VC(t-8)	1.0421	-0.1642	0.6933	3.7079	0.3829	2.3213
		(0.0500)	(0.0606)			(0.6487)	(0.0111)
FP(t-9)	VC(t-9)	0.9033††	0.1211**	0.7714	3.0019	-0.4716	1.3001
		(0.0526)	(0.0553)			(0.3191)	(0.0982)
FP(t-10)	VC(t-10)	0.8659††	0.1565**	0.7199	3.4380	0.0602	2.0058
		(0.0626)	(0.0583)			(0.5240)	(0.0237)
FP(t-11)	VC(t-11)	0.8056††	0.4604**	0.7927	2.8330	-0.7130	1.1624
		(0.0695)	(0.0558)			(0.2387)	(0.1239)
			Incurred Cost Models				
FP(t)	VC(t-5)	0.1969††	0.3124**	0.5116	5.1309	——	2.9319
		(0.1654)[c]	(0.0671)c				(0.0021)[d]
FP(t-1)	VC(t-5)	0.5899††	-0.0323	0.2899	6.1446	1.1994	9.9246
		(0.1482)	(0.0649)			(0.8835)[d]	(0.0001)
FP(t-2)	VC(t-5)	0.8410	-0.0480	0.3750	5.8856	0.7403	5.5278
		(0.1442)	(0.0644)			(0.7696)	(0.0001)
FP(t-3)	VC(t-5)	0.9605	0.0312	0.6212	4.2979	-0.7688	2.8902
		(0.1156)	(0.0720)			(0.2219)	(0.0023)
FP(t-4)	VC(t-5)	1.1605††	0.1983**	0.7983	3.1873	-1.8232	1.7279
		(0.0947)	(0.0777)			(0.0356)	(0.0435)
FP(t-5)	VC(t-5)	1.0894†	0.2422**	0.8841	2.1934	-2.9319	——
		(0.0589)	(0.0748)			(0.0021)	
FP(t-6)	VC(t-6)	1.1771††	-0.2105**	0.7852	3.1557	-1.9078	1.9120
		(0.0516)	(0.0805)			(0.0296)	(0.0293)
FP(t-7)	VC(t-7)	1.0324	-0.2513**	0.7115	3.4431	-1.5619	1.9469
		(0.0461)	(0.0648)			(0.0607)	(0.0271)
FP(t-8)	VC(t-8)	1.0587	-0.2013**	0.6785	3.7964	-1.2349	2.4694
		(0.0492)	(0.0610)			(0.1098)	(0.0076)
FP(t-9)	VC(t-9)	0.8962††	0.0787	0.7570	3.0951	-1.8554	1.4423
		(0.0513)	(0.0558)			(0.0332)	(0.0761)
FP(t-10)	VC(t-10)	0.8742††	0.1297**	0.7084	3.5075	-1.5002	2.0940
		(0.0614)	(0.0581)			(0.0683)	(0.0193)
FP(t-11)	VC(t-11)	0.8044††	0.4641**	0.7936	2.8264	-2.1178	1.1156
		(0.0699)	(0.0556)			(0.0183)	(0.1336)

†† and † denote significantly different from one at the 5 and 10 percent levels, respectively.

** and * denote significantly different from zero at the 5 and 10 percent levels, respectively.

[a] Statistic for the one-tailed test of whether or not the error variance of the model with FP(t) as the dependent variable is *greater* than the error variance of the remaining models.

[b] Statistic for the one-tailed test of whether or not the error variance of the model with FP(t-5) as the dependent variable is *smaller* than the error variance of the remaining models.

[c] Standard errors are in parentheses under parameter estimates.

[d] P-values are in parentheses under test stastics and denote the probability of rejecting the null hypothesis when the null is true.

with the cattle models, the error variance of the delivery month model was one of the largest, and the error variance of the model five months from delivery was one of the smallest.

The differences between the incurred cost and contemporaneous cost live hog model results were similar to the differences in the cattle model findings. The cost coefficients in the incurred cost system were insignificantly different from one at the two, three, five, seven, and eight month horizons. At the one month horizon and during the delivery month, movements in futures prices did not mirror movements in variable costs during the placement period. The deteriorating relationship was affirmed by the increasing root error variance from the models as the time-to-maturity horizon diminished. The findings suggested that the live hog futures contracts were priced in a manner consistent with rational price formation during periods prior to the commitment of animals to feed or at least where future supplies were not well known. Then, as the delivery month approached, the relationship between futures prices and costs at placement deteriorated.

Differences Between Live Cattle and Live Hogs

There were interesting differences between the live cattle and live hog futures prices and average cost of feeding relationships over different maturity horizons. Live cattle futures prices did not react to changes in cattle feeding variable costs as much as the live hog futures react to changes in hog feeding variable costs. In the live cattle models, the estimated cost coefficients were usually less than one, or were greater than one by less than one standard error. The live hog cost coefficients were, in most cases, greater than one with several being significantly greater than one. The results suggested that the live hog futures market was more sensitive to changes in variable costs. Alternatively, a significant portion of cattle slaughter are nonfed animals. The supply of these animals responds to changes in cattle prices but not to cattle feeding costs. The hog market has a smaller nonfed counterpart. The reactive nature of hog futures prices to cost changes also appeared in the autoregressive parameter and cross equation correlation results.

In the live cattle models, mild positive serial correlation of errors was observed. The exception was with the four and five months from delivery contemporaneous cost models where there was no significant serial correlation. Positive serial correlation suggested that there was a systematic component in the model not explained by costs or by the other independent variables, and that this systematic component adjusted slowly around the independent variable portion of the model. The live hog models reveal positive and negative serial correlation. The negative serial correlation suggested that if futures were priced at a premium to variable costs for one contract, at a given maturity, the following contract would be priced at a discount during the same distance from maturity, correcting for trends and seasonality. This reaffirms the reactive nature of the live hog futures prices in their movements around costs.

Cross equation correlations of errors are presented for the cattle systems in Table 3 and the hog systems in Table 4. The correlation between neighboring maturity month models was positive and relatively large for both cattle and hog systems. If futures for a given contract were priced at a premium (discount) to variable feeding costs during a particular calendar month, then it is likely that futures would be priced at a premium (discount) to costs one calendar month later. Most of the other correlations were close to zero with the exception of the negative correlations between placement period models and the delivery month model errors for the incurred cost system for cattle and the contemporaneous cost system for hogs.

The difference between cattle and hog correlations in the systems may be related to the extent of information in the respective markets. The contemporaneous cost system results for live cattle suggested that if futures were priced at a premium (discount) to contemporaneous costs they would continue to be priced at a premium (discount) over much of the contract life. This suggests that feeder animal supplies, and therefore live animal supplies, may be fixed to a degree over the trading horizon of a year. The incurred costs system results suggested that if futures were priced at a premium (discount) to variable feeding costs during some of the distant months (six and seven months from delivery) and after placements occur (two to four months from delivery), then futures would be priced at a discount (premium) to incurred variable costs during the delivery month. The live cattle futures market may provide overly pessimistic or optimistic profit margin outlooks two, three, four, six, and seven months from delivery, suggesting that there is, to some degree, a self-defeating supply response. The correlation between the premiums and discounts offered during the fifth month prior to delivery and the delivery month premiums and discounts was not significant.

Contemporaneous cost system correlations for the hog models confirmed the reactive nature of the market. Negative correlations between the three nearby month model errors and the model errors of the more distant months in the contemporaneous cost system suggested that premiums (discounts)

Table 3. Cross Equation Correlations of Errors for the Live Cattle Futures Prices / Variable Costs of Cattle Feeding Systems

	FP(t-1)	FP(t-2)	FP(t-3)	FP(t-4)	FP(t-5)	FP(t-6)	FP(t-7)	FP(t-8)	FP(t-9)	FP(t-10)	FP(t-11)
						Contemporaneous Cost Models					
FP(t)	0.6589	0.0550	-0.0609	0.1602	0.2194	0.1063	-0.0460	0.0864	0.2569	0.1031	0.0091
FP(t-1)		0.4436	0.1890	0.2558	0.3245	0.3150	0.2031	0.2688	0.3315	0.2381	0.1917
FP(t-2)			0.4610	-0.1136	0.0347	0.3734	0.3907	0.1652	-0.0504	0.0059	0.2611
FP(t-3)				0.4351	0.0551	0.1827	0.4588	0.4079	0.1660	0.1535	0.2543
FP(t-4)					0.6063	0.3112	0.3509	0.5005	0.4244	0.3164	0.1260
FP(t-5)						0.5687	0.4079	0.4792	0.5366	0.4664	0.2927
FP(t-6)							0.4280	0.2405	0.2563	0.2284	0.1958
FP(t-7)								0.6789	0.2309	0.1670	0.2960
FP(t-8)									0.6070	0.4184	0.3870
FP(t-9)										0.7865	0.4243
FP(t-10)											0.5453
						Incurred Cost Models					
FP(t)	0.5872	-0.2942	-0.4133	-0.2596	0.0053	-0.1731	-0.2143	-0.1015	-0.0018	-0.0628	-0.2593
FP(t-1)		0.3453	-0.1410	-0.1660	0.0101	0.0742	-0.0793	-0.1206	-0.0730	-0.0748	-0.1391
FP(t-2)			0.6907	0.2420	-0.0364	0.2917	0.2336	0.0505-	-0.1000	-0.0610	0.0726
FP(t-3)				0.5634	0.0455	0.2051	0.3518	0.2744	0.0632	0.0767	0.1155
FP(t-4)					0.2124	0.0615	0.2768	0.4113	0.2024	0.0199	0.0087
FP(t-5)						0.5410	0.3307	0.4230	0.5063	0.4295	0.2481
FP(t-6)							0.4337	0.2393	0.2601	0.2235	0.1901
FP(t-7)								0.6851	0.2731	0.1945	0.3061
FP(t-8)									0.6321	0.4546	0.4077
FP(t-9)										0.8010	0.4945
FP(t-10)											0.5817

offered early in the contract life were reversed as the contract matured. The incurred cost system correlations were primarily positive but small. The hog market, more so than the cattle market, did not offer incentives or disincentives early in the contract life that were later self-defeated by a supply response. This is consistent with the inflexible nature of hog feeding decisions once breeding decisions have been made. However, it appeared to take the live hog futures market four to six months to become comfortable with the supply numbers (initially available in bred sow intentions) and to begin to forecast future market conditions. This suggests some flexibility in slaughter of bred sows and young pigs, or in the use of gilts in the breeding herd. Compared with the live cattle market, the hog market appeared to be more nervous and reactionary. This may be due to informational differences between the markets. USDA inventory reports are released monthly for cattle but quarterly for hogs. The hog market must anticipate future supplies with variable cost of feeding information to a greater extent than the cattle market. The reactionary nature of the hog market appears appropriate given the absence of self-defeating supply responses measured in the incurred cost system correlations.

IMPLICATIONS FOR HEDGING

The presence of rational price formation in livestock futures markets suggests that cattle and hog producers need to approach preplacement hedging with realistic price objectives. Prices for live cattle futures contracts generally move in tandem with variable costs of feeding until the futures contract is two months from delivery. Prices for live hog futures contracts move with variable costs of feeding during the fifth month prior to delivery but react strongly to cost changes at other times. If cattle and hog producers have an objective of establishing profit margin hedges prior to placing the animals on feed, they

Table 4. Cross Equation Correlations of Errors for the Live Hog Futures Prices / Variable Costs of Hog Feeding Systems

	FP(t-1)	FP(t-2)	FP(t-3)	FP(t-4)	FP(t-5)	FP(t-6)	FP(t-7)	FP(t-8)	FP(t-9)	FP(t-10)	FP(t-11)
					Contemporaneous Cost Models						
FP(t)	0.3941	0.1683	0.0754	-0.0387	-0.1360	-0.0847	-0.1408	-0.0573	-0.0470	-0.0743	0.0018
FP(t-1)		0.4959	0.3330	-0.0557	-0.1088	-0.2348	-0.2243	-0.1762	-0.0975	-0.0896	-0.0513
FP(t-2)			0.4850	0.1345	-0.0303	-0.0772	-0.1079	0.0114	-0.0579	-0.0240	0.0301
FP(t-3)				0.4250	0.2979	0.2351	0.1340	0.1869	0.1041	0.1395	0.2999
FP(t-4)					0.5238	0.3804	0.3030	0.2997	0.1851	0.2806	0.1816
FP(t-5)						0.5504	0.3301	0.3859	0.2904	0.3349	0.1944
FP(t-6)							0.6740	0.6546	0.5109	0.5045	0.3203
FP(t-7)								0.8650	0.8044	0.7192	0.5858
FP(t-8)									0.8140	0.7651	0.5549
FP(t-9)										0.7493	0.5965
FP(t-10)											0.6639
					Incurred Cost Models						
FP(t)	0.6586	0.4479	0.2253	0.0346	-0.0539	0.0456	0.0481	0.1240	0.1082	0.1034	0.0906
FP(t-1)		0.8292	0.6229	0.3104	-0.0324	-0.0290	-0.0252	0.0505	0.1013	0.0886	0.1222
FP(t-2)			0.7934	0.4903	-0.0082	0.0630	0.0228	0.1409	0.1228	0.1355	0.1540
FP(t-3)				0.6377	0.1513	0.1615	0.0952	0.1562	0.0978	0.1450	0.2793
FP(t-4)					0.3728	0.2529	0.1758	0.2579	0.1891	0.2809	0.2333
FP(t-5)						0.5545	0.3377	0.3890	0.2976	0.3410	0.1948
FP(t-6)							0.6962	0.6688	0.5266	0.5169	0.3238
FP(t-7)								0.8555	0.7890	0.7108	0.5740
FP(t-8)									0.8267	0.7797	0.5628
FP(t-9)										0.7667	0.6131
FP(t-10)											0.6710

cannot expect to hedge substantially above variable feeding costs. Figures 2 and 3 are histograms of the probability of observing specific differences ($/cwt.) between futures prices and USDA variable costs of feeding. Figure 2 presents, for cattle, the probability of differences between costs five months from delivery and futures five months from delivery, and between costs five months from delivery and futures in the delivery month. The histograms were constructed using two dollar-per-hundredweight intervals; the midpoints of the intervals are indicated on the horizontal figure axes.

The probability of observing large positive or negative differences between futures prices and feeding costs incurred at placement was greater for the delivery month futures prices than for placement month futures prices. For example, in Figure 2, the probability of observing live cattle futures trading at a $2/cwt. or greater discount under USDA feeding budget figures during the placement period is less than 2 percent. However, during the delivery month, futures have been $2/cwt. or more under incurred costs 23 percent of the time.[11] The same phenomena hold for higher prices. Futures prices during the placement month have traded in excess of $4/cwt. above USDA feeding costs approximately 12 percent of the time. However, during delivery months futures have been in excess of incurred costs by $4/cwt. for approximately 40 percent of the time.

A similar pattern is revealed for hogs in Figure 3. Large positive or negative differences between futures prices and actual hog feeding costs were more likely to be observed in the delivery month than in the placement month. Futures prices have not been

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[11] Interval probabilities in the histogram were cumulated for this interpretation.

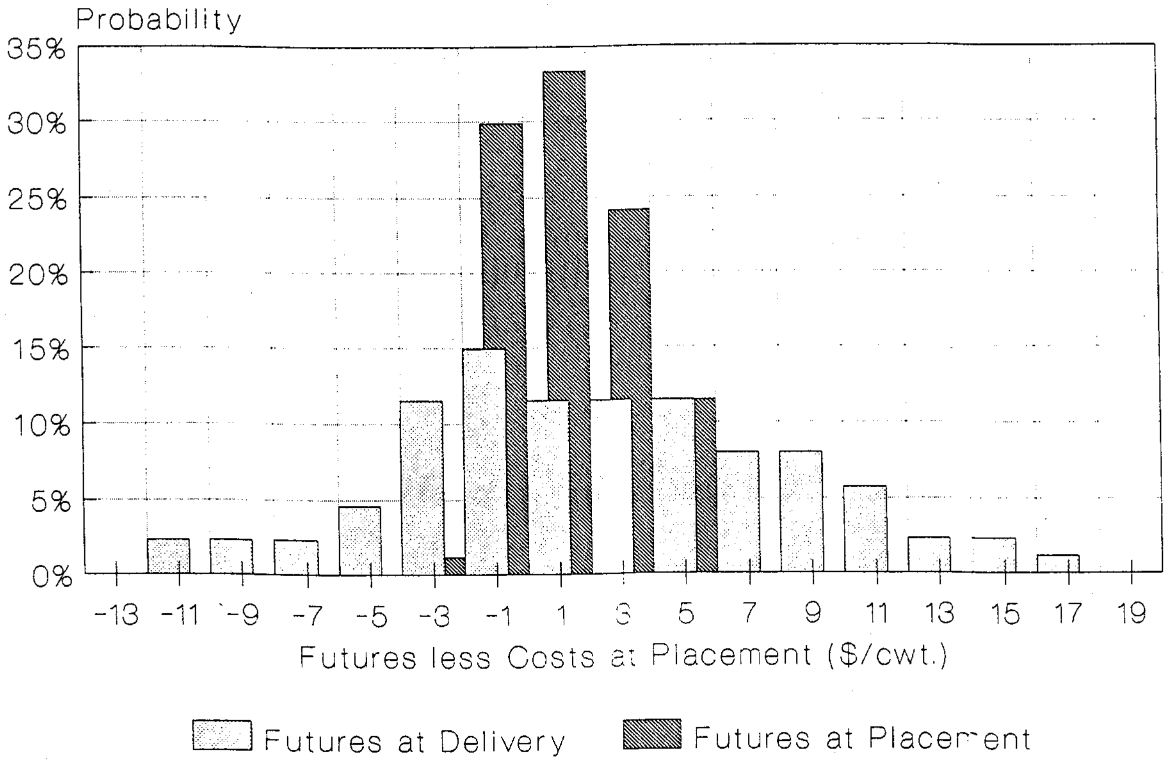

Figure 2. Histograms of the Difference Between Live Cattle Futures at Delivery and USDA Great Plains Cattle Feeding Costs at Placement and of the Difference Between Live Cattle Futures at Placement and USDA Great Plains Cattle Feeding Costs at Placement.

observed below USDA variable feeding costs five months prior to delivery. However, during the delivery month futures have been observed below the actual feeding costs 10 percent of the time. Likewise, futures prices have been observed in excess of feeding costs by $14/cwt. only 1 percent of the time during the placement month. However, during the delivery month, this difference has been observed 25 percent of the time.

Caution should be used in interpreting the level of the difference between futures prices and USDA average variable feeding costs as profits or, more accurately, as returns to fixed costs. The magnitudes may be biased upward, as USDA costs have been found to be higher than industry costs (Trapp). Further, the futures price must be adjusted for basis to obtain a cash price. The issue at hand is the wide spread between futures prices and cost at the time of delivery and the narrow spread during the placement months. Bias in returns to fixed costs will not affect the spreads observed. Therefore, if a cattle feedlot operator's feeding costs are consistently $2/cwt. lower than the USDA feeding budget, then it appears that the producer can establish a price, by hedging prior to placement, covering feeding costs more than 97 percent of the time. However, 88 percent of the time the feeder will earn less than $4/cwt. above variable costs by hedging prior to placement. This is the standard risk/return tradeoff of portfolio theory. Thus, the crucial observation is that the producer who hedges at or before placement can reduce the probability of losses, but very profitable returns are also eliminated.

CONCLUSIONS

Rational price formation is generally supported by the behavior of distant live cattle and live hog futures prices. Distant futures contracts trade at prices around the average costs of feeding during the time period when a supply response is possible. However, after feeding commitments are made, market prices likely adjust to reflect expected market conditions as those conditions become known. As a result, livestock futures markets forecast poorly at longer time horizons and improve as the contract nears maturity. Evidence of rational price formation suggests that an analytical framework which attempts to draw market efficiency conclusions based solely on forecast performance is too stringent because it ignores the arbitrage between futures markets and feeding decisions.

The live cattle futures market exhibits rational price formation to a greater degree than does the live hog futures market. This may be due to the level of

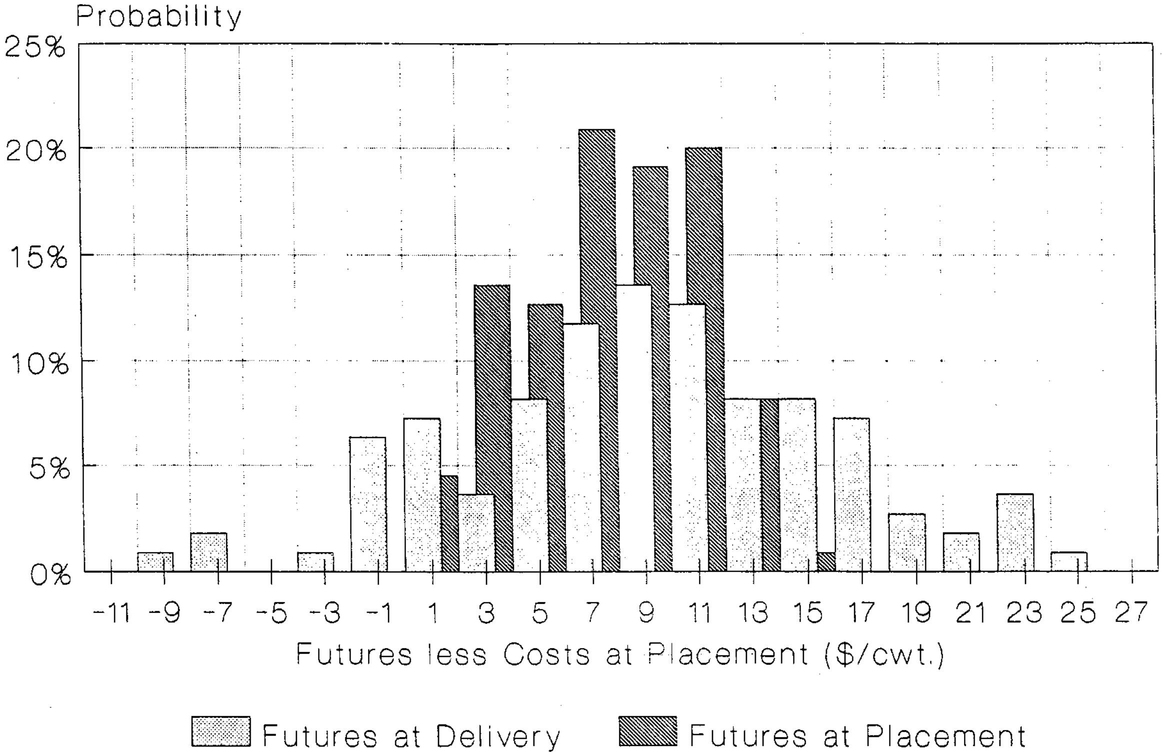

Figure 3. **Histograms of the Difference Between Live Hog Futures at Delivery and USDA Corn Belt Hog Feeding Costs at Placement and of the Difference Between Live Hog Futures at Placement and USDA Corn Belt Hog Feeding Costs at Placement.**

uncertainty in the respective production processes. In the hog market, there is more supply uncertainty because government reports are less frequent. Also, hog production may be more uncertain as it may be more influenced by weather, disease, birth rates, and other factors. For live cattle, the decision most affecting rational price formation is whether animals are finished or left in backgrounding programs. This difference between live cattle and live hog futures markets appears to merit further investigation.

From the viewpoint of the decision maker interested in using live cattle or hog futures markets to manage price risk, the results have implications for hedging strategy selection as well as for identifying the type of producer who can use futures to hedge effectively. The results suggest that the successful hedger will effectively manage costs and establish hedges when futures prices offer costs plus a reasonable rate of return. Rational price formation limits the futures market from offering significant profits during the phase of a contract's life when future supplies can still be influenced. The market does not offer significant losses during this time period either. Beyond the period when a supply response can occur, more profitable hedging opportunities may arise and a more selective approach to hedging may yield higher returns. However, the higher returns are offered only in exchange for the higher level of risk associated with having unhedged production after the supply response period, where there is potential for price decreases as the market accumulates information.

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