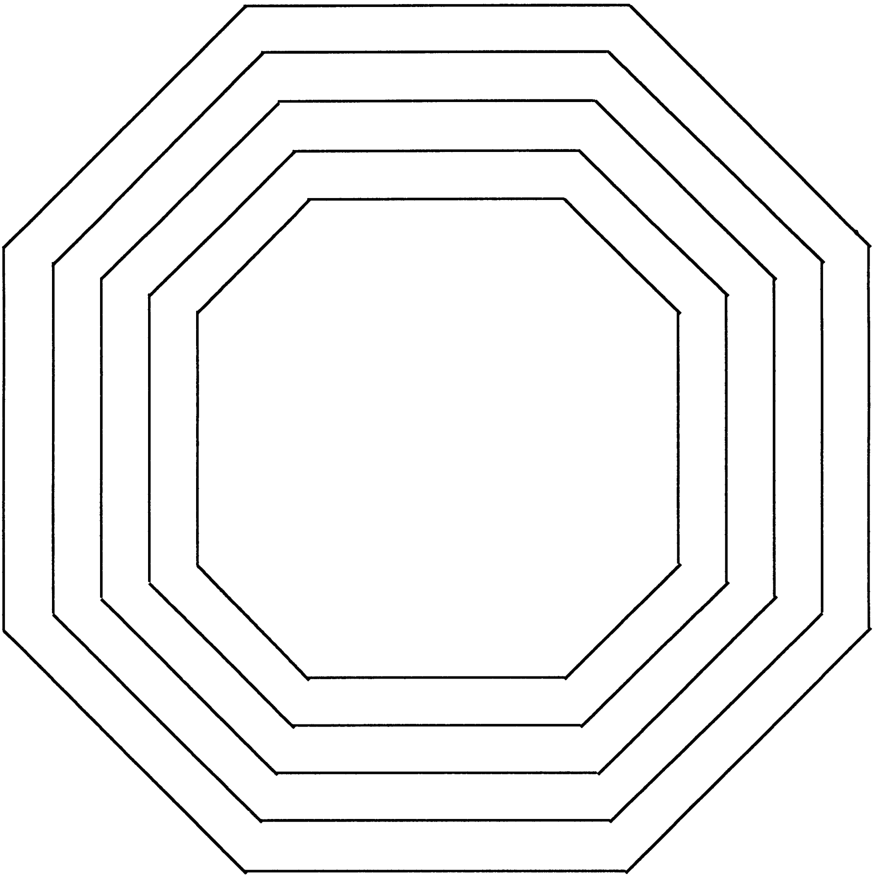
Rational Price Formation in Live Cattle and Live Hog Futures Markets



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Rational Price Formation in Live Cattle and Live Hog Futures Markets

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RATIONAL PRICE FORMATION IN LIVE CATTLE AND LIVE HOG FUTURES MARKETS

Introduction

In recent years, the efficiency of livestock futures markets has received increasing 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 stressed in analyses of market performance (Tomek and Gray; Peck 1985 and 1987). The first role, the allocative role, was investigated initially (Working) in a study of grain basis relationships and storage costs. For storable commodities, the availability of futures contracts deliverable up to a year, are thought to provide price incentives which influence storage decisions and thereby allocate grain consumption through time. 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). For nonstorable commodities, it has been argued that price levels of contracts deliverable up to a year should forecast anticipated supply and 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). Conclusions often drawn are that futures markets for nonstorables are inefficient, that speculators in these markets are not using all available information, and that *ex ante* welfare losses are incurred by society (Stein).

This bulletin examines the live cattle and live hog futures markets within the rational pricing framework suggested by Gray. It is argued that early in its life, a livestock futures contract trades in a price range around the expected break-even price given by the average costs of feeding. Early contract life is defined as the period when the supply to be marketed during the delivery month can be influenced by futures prices. Once the possibility of supply response is eliminated through production commitments (e.g., when the 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 bulletin 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. Implicit assumptions made when developing an empirical test are discussed in the fourth section. The models and data employed in the study are discussed in the fifth section. Section six presents the empirical results of the inquiry. In section seven, the implications of the results for hedging strategies are discussed. The paper finishes with concluding remarks.

Relevant Literature

The standard approach to assessing futures market efficiency assumes 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 futures market in predicting subsequent prices (Leuthhold; 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 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-storables, the futures market should play an allocative role while 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 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 nonstorables 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 responses and hence prices which will prove that reflection wrong" (p. 349). 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. Miller and Kenyon (1977) and Purcell et al. are the only attempts to examine the link between futures prices and cost of production in livestock markets. This bulletin identifies why futures markets for nonstorable commodities are not good forecasters, offers an alternative to the forward pricing role, which suggests that futures markets are pricing rationally even if they do not forecast well, and presents an empirical test for rational price formation illustrated with data from live cattle and live hog markets.

Rational Price Formation

Futures prices are more complex than a price forecast. Futures contracts are used to facilitate merchandising of the underlying commodity. 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 which 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 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 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.

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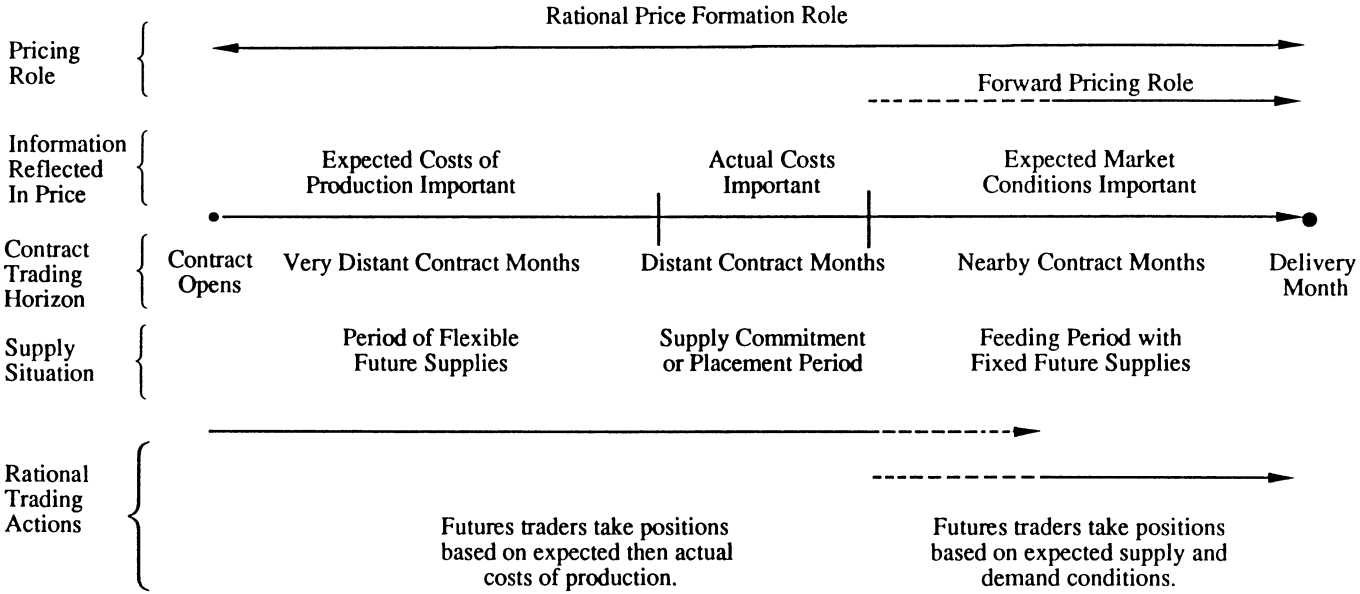
[1] Various analyses of feeding and marketing decisions made by cattle and hog producers suggest that these decisions are influenced by futures prices (Paul and Wesson; Ehrich; Miller and Kenyon 1977 and 1979; Hoffman 1979; Leuthold).

[2] This argument is true for trade between 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 for any one trade the hedger would likewise be irrational to guarantee a loss. Thus, ignoring the risk premium does not invalidate the argument.

[3] Arguments made by Helmuth, which suggest 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 live cattle contracts.

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



There is a pool of resources available to produce fed animals. The futures market assists in allocating these resources to production by 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 are as yet 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 the underlying idea of the rational expectations concept (Dewbre).

Modeling Assumptions

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 one-year contract, eminent 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 which 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" are used interchangeably. In cattle and hog feeding, animals marketed 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 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 considerably less flexibility in slaughter hog marketing. Empirical results should reveal when supplies go from being flexible to fixed by when futures prices no longer move with average 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) are 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 make the transition from reflecting feeding costs to reflecting expected market conditions. (The transition is illustrated by both sets of the overlaping dashed arrows in figure 1.) For example, hog supplies may be fixed once breeding decisions 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 is a researchable issue, but it does not affect the conceptualization of rational price formation or the empirical models.

Models and Data

The test for rational price formation in live cattle and live hog futures markets uses regressions of feeding costs on futures contract prices.

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[4] This is supported by USDA figures. Numbers from monthly cattle on feed reports suggest that five to seven percent of cattle removed from feedlots are not marketed as finished animals. This includes death loss also. 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 as a whole because the breeding herd is approximately 15 percent of the size of the market hog herd.

Monthly feeding costs are regressed on futures prices at various months from delivery. The basic model is

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

where i and j = 0,...,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 are twelve models involved in the test reflecting futures contract prices over the twelve month horizon that contracts are traded, i = 0,...,11 (j is specified below). The models are 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 are 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 600 lb. feeder steers are purchased and fed 1500 lbs. of milo, 1500 lbs. of corn, 400 lbs. of cotton seed meal, and 800 lbs. of alfalfa hay over six months and are sold at 1056 lbs. (1100 lbs. less four percent shrink). Corn Belt hog feeding budgets assume 40-50 lb. feeder pigs are purchased and fed 11 bu. of corn and 130 lbs. of protein supplement over five months and are sold at 220 lbs. All feed is bought at the time of feeder animal purchase.[6] The monthly Great Plains cattle feeding cost series is available from February 1975, to the present. The monthly Corn Belt hog feeding cost series is available from July 1973, to the present. Futures contracts used in the analysis include all live cattle contracts traded from the February 1975 through

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

[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. Feed futures contract prices across contract months are related primarily by storage costs. The practice of hedging total feed use at placement is common among commercial feeders.

the December 1989 contract, and all live hog contracts traded between their introduction with the June 1974 contract through the December 1989 contract. Average of daily closing prices were constructed for each contract month and each calendar month across the twelve-month trading horizon. The futures data were gathered from the *CME Handbooks* and the *Wall Street Journal*. There are 90 and 110 observations for each of the live cattle and live hog models.[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 (gains from implants and genetics) and seasonal low-cost substitutions by feedlot operators (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*) is approximated with a cubic time trend and series of monthly dummy variables. The expression used to capture aggregate U.S. variable costs is

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

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. Substituting (2) into the regression (1) and combining parameters and error terms yields

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

the estimable model.

The model is examined under two alternative specifications of j (where $i = 0,\ldots,11$) resulting in two systems of equations. The first system pairs futures prices with contemporaneous costs, or $j = i$. The second system pairs futures prices with incurred costs, or $j = i$ for i greater than the feeding period and when i less than the feeding period, j is equal to the number of months in the feeding period. In other words, in the contemporaneous cost system, futures prices in the delivery month are modeled as a function of feeding costs in the delivery month; futures prices one month from delivery are modeled as a function of feeding costs one month from delivery. To complete the system, analogous models are constructed where futures prices two through eleven months from

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

delivery are modeled 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 prior to the placement period, are modeled 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 are included.[8] Both of these systems will provide evidence about the existence of rational price formation.

The contemporaneous cost system models futures prices as a function of actual costs over three trading horizons identified in figure 1. The focus of the system is 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 being fixed, or at least when information on future supplies becomes known. This is the time period when traders will 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 is recognized. However, time series properties of the cost data suggest this approximation is appropriate. After accounting for trend and seasonality, the monthly cost series is essentially random. Thus, the best forecast for costs one to twelve months ahead is the current actual cost level (given the models incorporate trends and seasonality). Appendix A presents a summary of the time series characteristics of the cattle and hog cost of feeding series. Further, the potential limitation is defused in that conclusions about rational price formation are made cautiously with evidence from the very distant contract month models.

The incurred cost system provides additional evidence about the presence of rational price formation. This system highlights 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 if 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 negative errors imply a discount. Negative correlations between placement period model errors and delivery month model errors imply premiums (discounts) during the placement period trigger behavior by livestock feeders that results in discounts (premiums) during the delivery month.

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[8] For the contemporaneous costs models $i = j = 0,\dots,11$. For the incurred costs models $j = 5$ if $i = 0,\dots,4$. That is, futures prices less than five months from delivery are modeled as a function of costs incurred five months prior to delivery. The exact specification of the systems are shown in table 1.

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 symmetric price adjustments after the placement period may result in the appearance that prices continue to move with costs during the 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 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 cross equation correlation was persistent in both and that seemingly unrelated regressions are appropriate (Breusch and Pagan). Error diagnostics also suggest that a majority of the models in the two systems exhibit first-order serial correlation (Kiviet). The results that follow are from models estimated via iterative seemingly unrelated regressions corrected for first-order serial correlation. Appendices B and C present discussions of the statistical tests for serial correlation and cross equation correlation and present the test results. 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 is: $j = 5$ for $i = 0,...,5$ and $j = i$ for $i = 6,...,11$.[9] As a whole, results support 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. Complete parametric results are contained in Appendix D. Parameter estimates for the seasonal dummy variables were as expected, suggesting significant seasonal variations in variable costs of feeding not captured by USDA budgets. Polynomial trend variables are not included in the final specification of live cattle systems. The mean squared errors of models with trend variables are larger than those of models with only seasonal factors.

Regression results linking feeding costs to live cattle futures prices over various times to contract maturity are 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 are insignificantly different from one, starting with the delivery month model, through the model of prices seven months from delivery. The cost coefficient is significantly different from one at the ten percent level in the eight and nine month models, and at the five percent level in the ten and eleven month models. The coefficients are smaller than one in these cases, suggesting that futures do not adjust fully to cost changes in 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 are 1.0127 (0.0235), 1.0180 (0.0223), and 0.9907 (0.0316).

The cost coefficient standard errors and root error variances decline as the time to contract maturity increases from the delivery month to five months prior to delivery and remain fairly constant thereafter. The root error variance is \$3.43/cwt. for the delivery month model and decreases to \$2.04/cwt. for the model of prices five months from delivery. Table 1 also presents two t-statistics which test whether the error variance of the delivery month model ($i = 0$) is greater than the error variance for each of the other models (t-test 1),

$$(4)\quad H_{oi}:\ \sigma_0^2 > \sigma_i^2 \ \text{ for } i = 1,...,11$$

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[9] 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)[d]
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)

†† and † denote significantly different from one at the five and ten percent levels.

** and * denote significantly different from zero at the five and ten percent levels.

[a] Statistic for the one-tailed test of whether or not the error variance of the model with FP(t) as 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 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 statistics and denote the probability of rejecting the null hypothesis when the null is true.

Table 1 (continued). 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]
			Incurred Cost Models				
FP(t)	VC(t-5)	-0.3550†† (0.1854)[c]	0.9549** (0.0359)[c]	0.8185	4.5039	------	2.3963 (0.0094)[d]
FP(t-1)	VC(t-5)	0.1513†† (0.1681)	0.8863** (0.0504)	0.8491	4.0121	-0.5907 (0.2782)[d]	5.6407 (0.0001)
FP(t-2)	VC(t-5)	0.9029†† (0.0575)	0.2119** (0.0660)	0.8404	4.0928	-0.4216 (0.3372)	4.0497 (0.0001)
FP(t-3)	VC(t-5)	0.9845 (0.0411)	0.1129 (0.0714)	0.9080	3.1001	-1.3962 (0.0833)	2.5243 (0.0068)
FP(t-4)	VC(t-5)	0.9984 (0.0404)	0.3011** (0.0823)	0.9406	2.4675	-1.9635 (0.0265)	1.2708 (0.1037)
FP(t-5)	VC(t-5)	1.0234 (0.0250)	0.1308 (0.0843)	0.9650	1.9065	-2.3963 (0.0094)	------
FP(t-6)	VC(t-6)	0.9883 (0.0328)	0.2912** (0.0824)	0.9587	2.0262	-2.2764 (0.0127)	0.3106 (0.3785)
FP(t-7)	VC(t-7)	0.9943 (0.0293)	0.3069** (0.0752)	0.9670	1.8448	-2.3716 (0.0101)	-0.1334 (0.5529)
FP(t-8)	VC(t-8)	0.9776 (0.0246)	0.1096** (0.0714)	0.9598	1.9942	-2.2463 (0.0137)	0.1894 (0.4251)
FP(t-9)	VC(t-9)	0.9775 (0.0254)	0.0317 (0.0711)	0.9512	2.2523	-2.0843 (0.0202)	0.8422 (0.2011)
FP(t-10)	VC(t-10)	0.9622† (0.0269)	0.1779** (0.0700)	0.9598	2.0068	-2.2827 (0.0126)	0.2375 (0.4064)
FP(t-11)	VC(t-11)	0.9460† (0.0339)	0.3403** (0.0782)	0.9600	2.0264	-2.3041 (0.0119)	0.2835 (0.3888)

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†† and † denote significantly different from one at the five and ten percent levels.

** and * denote significantly different from zero at the five and ten percent levels.

[a] Statistic for the one-tailed test of whether or not the error variance of the model with FP(t) as 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 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 statistics and denote the probability of rejecting the null hypothesis when the null is true.

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

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

Usually testing the difference between variances involves an F-statistic. However, this requires that the underlying random variables be independent. Model errors within both systems are dependent random variables. Therefore, the t-test outlined in Cox and Hinkley (p. 140-1) is used. Appendix D presents details and a discussion of the test.

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

The incurred cost system displays results similar to the contemporaneous cost system. The only difference is that, as expected, the cost coefficients during the delivery and a nearby month are significantly different from one. One month prior, and during the delivery month, futures prices are unrelated to actual costs incurred five months prior. The root error variance is $4.50/cwt. for the delivery month model and decreases to $1.91/cwt. for the model of prices five months from delivery. The t-statistics for the incurred cost system reveal an almost identical pattern as that of the contemporaneous cost system. The error variance is 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 support rational price formation in the distant contract months. Futures prices consistently move with costs of feeding from seven months prior to delivery until the delivery month. However, this relationship begins to deteriorate two months from delivery, and has severely deteriorated one month from and during the delivery month. Up until two months prior to the delivery month, futures continue to reflect incurred costs of feeding. Between two months prior and the delivery month, futures move with costs, but in a less systematic fashion. During the delivery month, the standard error and the root error variance are the largest of any of the months over the trading horizon.

Live Hog Futures

Similar to the live cattle model results, results for live hog futures models support rational price formation, although they are somewhat less conclusive. Table 2 presents a portion of the findings, with the trend and seasonal results excluded. Complete results are presented in appendix C. The trend and seasonal results were as expected. Feeding costs exhibit a trend which is declining at a decreasing rate, and seasonal variations which are not captured in the USDA budgets.

The estimated cost coefficient β_1, autoregressive error parameter ρ, R-square, 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 are significantly different from one. However, the cost coefficient in the model of futures prices seven months from delivery is not significantly different from one at the ten percent level, and the cost coefficients in the five and eight months from delivery models are not significantly different from one at the five percent level. Most importantly, during the feeding commitment month, the fifth month prior to delivery, the cost coefficient is 1.0448 with a standard error of 0.0567. Futures move with costs very closely during this period. The root error variance of the models are largest in the nearby and most distant months. The smallest root error variance is in the fifth month model. This suggests futures are most influenced by costs during the month when animals are committed to the feeding process. However, actual costs may not approximate expected future costs well in the very distant contract month models.

Table 2 also reports t-statistics examining the difference between 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 with the cattle models, the error variance of the delivery month model is one of the largest, and the error variance of the model five months from delivery is one of the smallest.

The differences between the incurred cost and contemporaneous cost live hog model results are similar to the differences in the cattle model findings. Cost coefficients in the incurred cost system are 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 do not mirror movements in variable costs during the placement period. The deteriorating relationship is affirmed by the increasing root error variance from the models as the time to maturity horizon diminishes. The findings suggest that live hog futures contracts are priced in a manner consistent with rational price

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)

†† and † denote significantly different from one at the five and ten percent levels.

** and * denote significantly different from zero at the five and ten percent levels.

[a] Statistic for the one-tailed test of whether or not the error variance of the model with FP(t) as 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 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 statistics and denote the probability of rejecting the null hypothesis when the null is true.

Table 2 (continued). 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]
			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)

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†† and † denote significantly different from one at the five and ten percent levels.

** and * denote significantly different from zero at the five and ten percent levels.

[a] Statistic for the one-tailed test of whether or not the error variance of the model with FP(t) as 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 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 statistics and denote the probability of rejecting the null hypothesis when the null is true.

formation during periods prior to commitment of animals to feed, or at least where future supplies are not well known. Then as the delivery month approaches, the relationship between futures prices and costs at placement deteriorates.

Differences Between Live Cattle and Live Hogs

There are interesting differences between live cattle and live hog futures/cost relationships over different maturity horizons. Live cattle futures prices do not react to changes in cattle feeding variable costs as much as live hog futures react to changes in hog feeding variable costs. In live cattle models, the estimated cost coefficients are usually less than one, or are greater than one by less than one standard error. The live hog cost coefficients are, in most cases, greater than one with several being significantly greater than one. The results suggest that the live hog futures market is 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 slaughter hog market has a much smaller nonfed counterpart. The reactive nature of hog futures prices to cost changes also appears in the autoregressive parameter and cross equation correlation results.

In live cattle models, mild positive serial correlation is observed. The exception is with the four and five months from delivery contemporaneous cost models, where there is no significant serial correlation. Positive serial correlation suggests there is a systematic component in the model not explained by costs or other independent variables, and that this systematic component adjusts slowly around the independent variable portion of the model. The live hog models reveal positive and negative serial correlation. The negative serial correlation suggests that if futures are priced at a premium to variable costs for one contract, at a given maturity, the following contract will 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 are presented for the cattle systems in table 3 and the hog systems in table 4. The correlation between neighboring maturity month models is positive and relatively large for both cattle and hog systems. If futures for a given contract are priced at a premium (discount) to variable feeding costs during a particular calendar month, then it is likely futures will be priced at a premium (discount) to costs one calendar month later. Most of the other correlations are close to zero, with 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

Table 3. Cross Equation Correlations 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

Table 4. Cross Equation Correlations 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)						0.5540	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

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 suggest that if futures are priced at a premium (discount) to contemporaneous costs, they will 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 suggest that if futures are 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 will 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 to some degree, a self-defeating supply response. The correlation between premiums and discounts offered during the fifth month prior to delivery and the delivery month premiums and discounts is not significant.

Contemporaneous cost system correlations for the hog models confirm 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 suggest that premiums (discounts) offered early in the contract life are reversed as the contract matures. The incurred cost system correlations are primarily positive, but small. The hog market, more so than the cattle market, does not offer incentives or disincentives early in the contract life which are 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 appears 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 appears 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 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 cannot expect to hedge substantially above variable feeding costs. Figures 2 through 5 are histograms and cumulative 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. All histograms are 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 is greater for delivery month futures prices than for placement month futures prices. For example, in figure 3, the probability of observing live cattle futures trading at a $2/cwt. or more discount under USDA feeding budget figures during the placement period is less than two percent. However, during the delivery month futures have been $2/cwt. or more under incurred costs 23 percent of the time. The same phenomena holds 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, futures have been in excess of incurred costs by $4/cwt. approximately 40 percent of the time during delivery months.

Similar patterns are revealed in figures 4 and 5 for hogs. Large positive or negative differences between futures prices and actual hog feeding costs are more likely to be observed in the delivery month than in the placement month. Futures prices have not been observed below USDA variable feeding cost five months prior to delivery. However, futures have been observed below the actual feeding costs ten percent of the time during delivery months. From figure 5, futures prices have been observed in excess of feeding costs by $14/cwt. only one 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 difference between futures prices and USDA average variable costs of feeding. The

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.

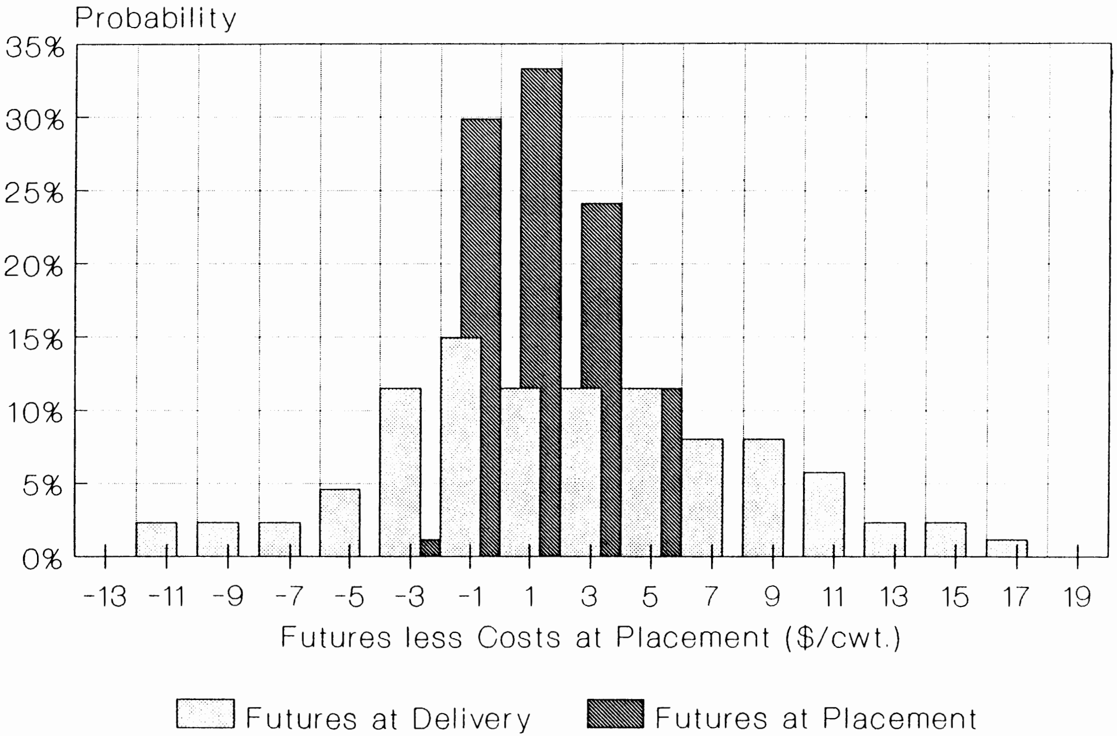


Figure 3. Cumulative Histograms of the Difference Between Live Cattle Futures at Delivery and USDA Great Plains Cattle Feeding Costs at Placement and of the Difference Between Live Cattle Futures at Placement and USDA Great Plains Cattle Feeding Costs at Placement.

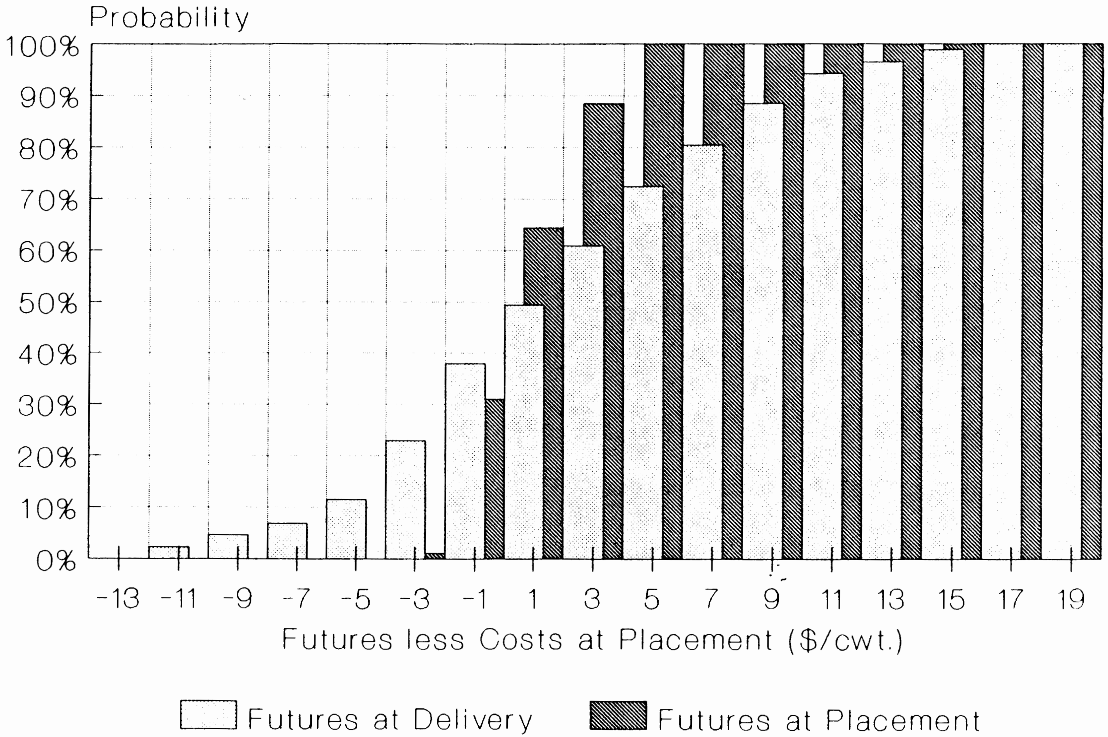


Figure 4. Histograms of the Difference Between Live Hog Futures at Delivery and USDA Corn Belt Hog Feeding Costs at Placement and of the Difference Between Live Hog Futures at Placement and USDA Corn Belt Hog Feeding Costs at Placement.

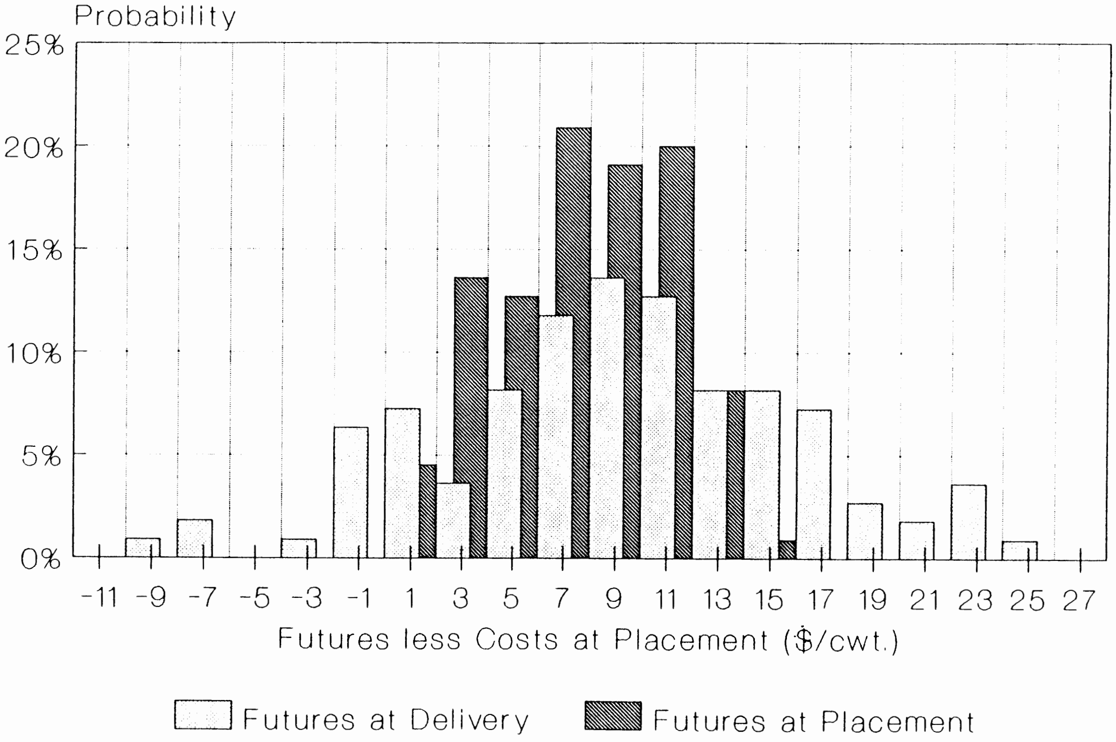
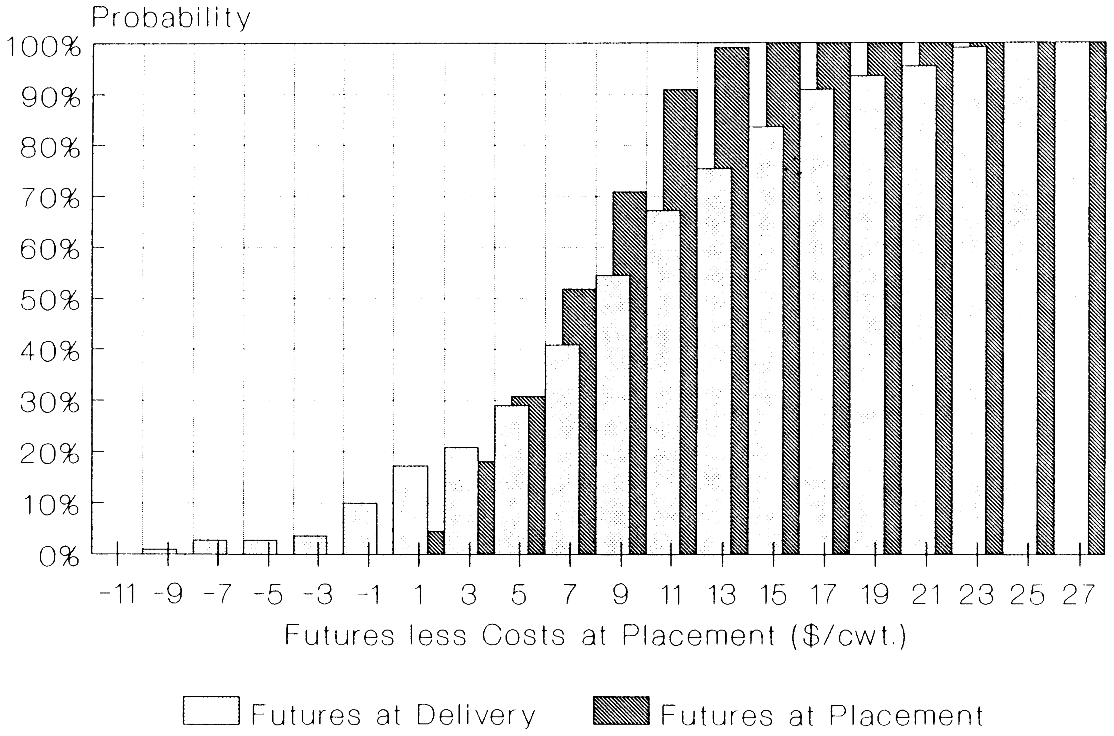


Figure 5. Cumulative Histograms of the Difference Between Live Hog Futures at Delivery and USDA Corn Belt Hog Feeding Costs at Placement and of the Difference Between Live Hog Futures at Placement and USDA Corn Belt Hog Feeding Costs at Placement.



level does not necessarily reflect feeding profits or, more accurately, returns to fixed costs. The magnitudes may be upward biased. USDA costs have been found to be higher than industry costs (Trapp). The futures price must be adjusted for basis to convert it to a local cash price. Basis is typically negative in regions of intensive production. The issue at hand is wide spread between futures prices and costs at delivery and the narrow spread during placement months. Bias in the returns to fixed costs numbers will not affect the spreads observed. Therefore, if a cattle feedlot operator's costs are consistently $2/cwt. lower than the USDA feeding budget, then it appears the producer can establish a price, by hedging prior to placement, covering feeding costs better 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 they 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 the live hog futures market. This may be due to the level of uncertainty in the respective production processes. There is more supply uncertainty in the hog market because of less frequent government reports. 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 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.

Appendix A

The regression models of variable feeding costs on futures prices for distant contract months assume expected costs at the time of placement can be approximated with current actual costs. As an example, futures prices eight months from delivery are modelled as a function of the then current variable feeding costs and seasonality. The true specification would be to model futures prices as a function of variable feeding costs expected at the time of placement, two to three months in the future, or the costs anticipated when the futures contract is five to six months from delivery. Industry expected costs of feeding are not available. As an alterative, the stochastic process influencing observed variable costs of cattle and hog feeding are examined to see if current actual costs can be used to approximate future expected costs of feeding.

Figures A.1 and A.2 present autocorrelations (AC) and partial autocorrelations (PAC) of the differenced variable cost of Great Plains cattle feeding and Corn Belt hog feeding out to fifteen months lagged. First differencing removes the trend from each series. Also reported are two standard errors for the autocorrelations and partial autocorrelations above and below zero. Autocorrelations are useful for identifying moving average processes in the series while partial autocorrelations identify autoregressive processes in the series. For example, a simple autoregressive process of order three would result in significant partial autocorrelations out to three lags and the remaining partial autocorrelations would be essentially zero. A simple moving average process of order two would result in significant autocorrelations out to two lags and the remaining autocorrelations would be essentially zero. More complex processes are more difficult to identify.

The overall results for the cattle and hog variable cost series suggest each exhibits first-order, eleventh-order and twelfth-order autoregressive processes. Basically, the cost series are first-order autoregressive with a seasonal pattern. When autoregressive parameters for these processes are fit to the data the residuals are random. This suggests that current actual costs are a good forecast of future actual costs when seasonality and the first-order autoregressive process is considered. The regression models incorporate seasonality and first-order autocorrelation thus, the approximation of expected costs with actual current costs should be appropriate.

Figure A.1 Autocorrelations, Partial Autocorrelations, and Standard Errors for the Variable Costs of Great Plains Cattle Feeding Series.

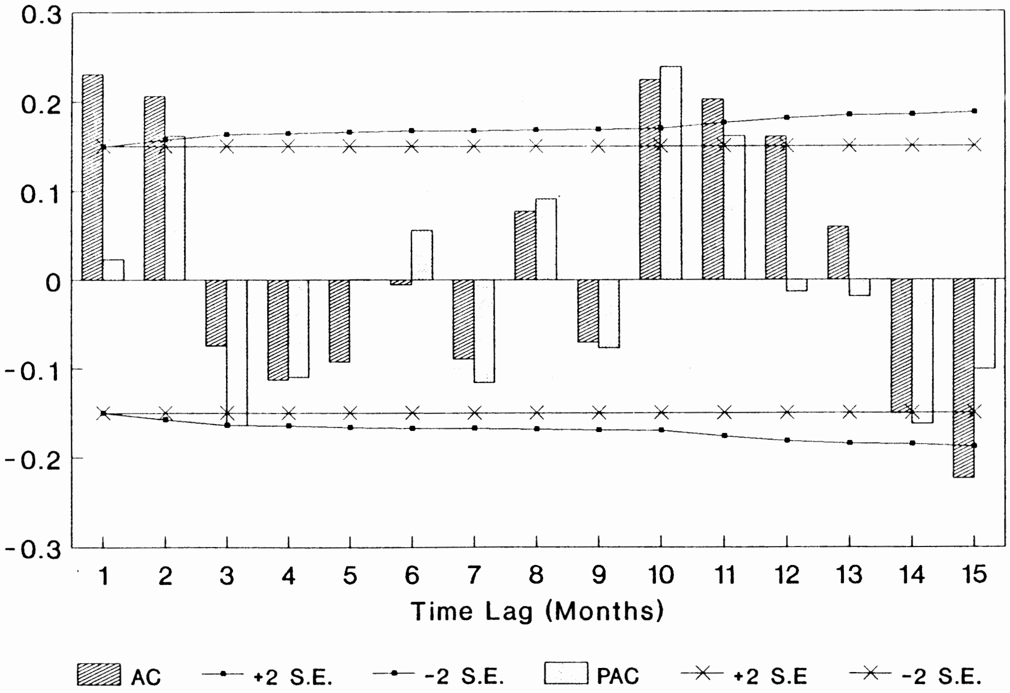
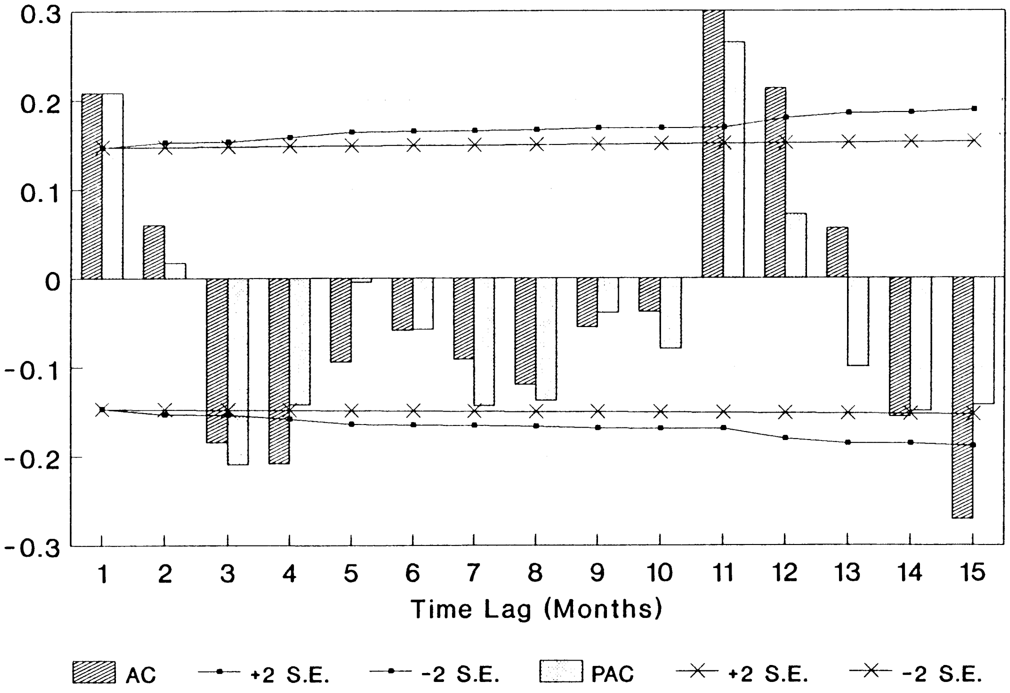


Figure A.2 Autocorrelations, Partial Autocorrelations, and Standard Errors for the Variable Costs of Corn Belt Hog Feeding Series.



Appendix B

The Lagrange multiplier test for serial correlation in regression model involves a second-stage regression of the least squares error term on lagged values of the error term and the model data set (Breusch and Pagan). The test regression is

$$\varepsilon_k = \sum_{i=1}^{p} \alpha_i \varepsilon_{k-i} + \sum_{j=1}^{b} x_{jk} \beta_j + e_k$$

where *k* denotes the time series of observations, *p* is the order of serial correlation under test, and the x_k denotes a row in the data matrix with *b* elements containing a constant term, variable feeding costs, trend variables, and seasonal dummy variables. The uncentered R-square from this regression multiplied by the number of observations is asymptotically distributed chi-square with *p* degrees of freedom under the null hypothesis of no serial correlation.

Kiviet has shown an asymptotically equivalent procedure with better small sample properties involves performing an F-test on the parameters associated with the lagged residuals. A significant F-test rejects the hypothesis of no serial correlation and the significance of the individual parameters provides information on the order of the serial correlation process in the error term.

The following tables present F-statistics testing for first-order through sixth-order serial correlation in the futures price / variable cost of feeding models for live cattle and first-through seventh-order serial correlation in live hog models. There are six live cattle contracts and seven live hog contracts traded per year. Thus, this specification examines lagged residuals for serial correlation patterns up to one year in length. Also presented are the significance levels of the parameter estimates of the lagged residuals. The results conclusively suggest first-order serial correlation is present in most of the models of live cattle and live hog futures price / variable costs of feeding relationships.

Table B.1 Lagrange Multiplier-Like Tests Examining for Serial Correlation in the Error Terms of the Contemporaneous and Incurred Cost Cattle Models.

Dependent and Independent Variables		F-Test[a]	P-Value	P-Values on the k-p Lagged Residual					
				p=1	p=2	p=3	p=4	p=5	p=6
FP(t)	VC(t)	5.5445	0.0001	0.0002	0.7634	0.1177	0.9994	0.0104	0.1767
FP(t-1)	VC(t-1)	2.2715	0.0477	0.0070	0.9727	0.9347	0.8739	0.2390	0.9060
FP(t-2)	VC(t-2)	1.4072	0.2259	0.1058	0.2707	0.7428	0.9006	0.4661	0.7435
FP(t-3)	VC(t-3)	3.9314	0.0021	0.0051	0.1002	0.6653	0.4298	0.3122	0.1429
FP(t-4)	VC(t-4)	2.8218	0.0170	0.0409	0.0206	0.9472	0.4943	0.9037	0.5288
FP(t-5)	VC(t-5)	6.0869	0.0001	0.0043	0.0078	0.5414	0.8135	0.4207	0.2062
FP(t-6)	FP(t-6)	3.2262	0.0079	0.0025	0.1669	0.5326	0.9985	0.5816	0.5991
FP(t-7)	VC(t-7)	4.8460	0.0004	0.0004	0.2856	0.8026	0.9583	0.2475	0.2338
PF(t-8)	VC(t-8)	3.3954	0.0058	0.0012	0.3334	0.6499	0.8021	0.5661	0.8287
FP(t-9)	VC(t-9)	4.5175	0.0007	0.0003	0.7715	0.9409	0.7999	0.0945	0.2358
FP(t-10)	VC(t-10)	4.1947	0.0013	0.0003	0.7016	0.8035	0.8942	0.4406	0.7679
FP(t-11)	VC(t-11)	5.3103	0.0002	0.0001	0.5265	0.6200	0.2940	0.6457	0.3477

Dependent and Independent Variables		F-Test[a]	P-Value	P-Values on the k-p Lagged Residual					
				p=1	p=2	p=3	p=4	p=5	p=6
FP(t)	VC(t-5)	9.1916	0.0001	0.0001	0.1501	0.8796	0.5630	0.0061	0.1399
FP(t-1)	VC(t-5)	5.5796	0.0001	0.0007	0.1485	0.8345	0.5973	0.0100	0.9449
FP(t-2)	VC(t-5)	2.5433	0.0287	0.0706	0.0967	0.8012	0.2995	0.0872	0.3706
FP(t-3)	VC(t-5)	1.2569	0.2901	0.4377	0.6787	0.7332	0.6816	0.0637	0.3762
FP(t-4)	VC(t-5)	1.8210	0.1092	0.0191	0.6371	0.3969	0.9247	0.0604	0.4398
FP(t-5)	VC(t-5)	6.0801	0.0001	0.0043	0.0078	0.5401	0.8155	0.4233	0.2073

[a] The F-Statistic is distributed F(6,63) under the null hypothesis of no serial correlation.

Table B.2 Lagrange Multiplier-Like Tests Examining for Serial Correlation in the Error Terms of the Contemporaneous and Incurred Cost Cattle Models.

Dependent and Independent Variables		F-Test[a]	P-Value	P-Values on the k-p Lagged Residual						
				p=1	p=2	p=3	p=4	p=5	p=6	p=7
FP(t)	VC(t)	5.7272	0.0001	0.0010	0.0021	0.5045	0.3714	0.4271	0.9506	0.8621
FP(t-1)	VC(t-1)	2.3618	0.0305	0.0034	0.9128	0.2247	0.2291	0.0643	0.8548	0.3747
FP(t-2)	VC(t-2)	0.7127	0.6613	0.2478	0.6695	0.9730	0.7807	0.2684	0.8266	0.3687
FP(t-3)	VC(t-3)	3.6935	0.0017	0.0001	0.0486	0.5169	0.0249	0.0022	0.0064	0.0704
FP(t-4)	VC(t-4)	2.1772	0.0452	0.0031	0.6372	0.9586	0.4892	0.4933	0.5684	0.8971
FP(t-5)	VC(t-5)	2.9547	0.0085	0.0003	0.5241	0.6932	0.4054	0.6065	0.8564	0.7212
FP(t-6)	FP(t-6)	5.2525	0.0001	0.0044	0.1931	0.2792	0.0769	0.0425	0.5532	0.8838
FP(t-7)	VC(t-7)	7.8821	0.0001	0.0001	0.3163	0.5726	0.0646	0.7677	0.4969	0.2144
PF(t-8)	VC(t-8)	12.7551	0.0001	0.0001	0.3014	0.6683	0.5144	0.4763	0.6329	0.0344
FP(t-9)	VC(t-9)	13.1931	0.0001	0.0001	0.2235	0.4613	0.9977	0.0329	0.8040	0.0547
FP(t-10)	VC(t-10)	11.3792	0.0001	0.0001	0.0869	0.8103	0.8236	0.1466	0.8569	0.1042
FP(t-11)	VC(t-11)	19.3705	0.0001	0.0001	0.8985	0.5743	0.0991	0.0098	0.5825	0.1671

Dependent and Independent Variables		F-Test[a]	P-Value	P-Values on the k-p Lagged Residual						
				p=1	p=2	p=3	p=4	p=5	p=6	p=7
FP(t)	VC(t-5)	17.0550	0.0001	0.0001	0.5422	0.5030	0.9406	0.2273	0.3086	0.0014
FP(t-1)	VC(t-5)	13.3859	0.0001	0.0001	0.4688	0.3996	0.2449	0.0460	0.1865	0.0013
FP(t-2)	VC(t-5)	8.4894	0.0001	0.0001	0.2921	0.5319	0.3339	0.4021	0.0704	0.0066
FP(t-3)	VC(t-5)	4.4193	0.0004	0.0005	0.2001	0.2473	0.8180	0.0034	0.5335	0.1788
FP(t-4)	VC(t-5)	4.5870	0.0002	0.0001	0.6275	0.2120	0.1847	0.3050	0.6603	0.5708
FP(t-5)	VC(t-5)	2.9547	0.0085	0.0003	0.5241	0.6932	0.4054	0.6065	0.8564	0.7212

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[a] The F-Statistic is distributed F(7,78) under the null hypothesis of no serial correlation.

Appendix C

The Lagrange multiplier test for cross equation correlation between the model error terms in a potential system of seemly unrelated regressions involves examining the correlation between least squares errors of the models in the potential system (Breusch and Pagan). In model notation, define the vector of error terms at observation *k* as

$$\varepsilon_k = (\varepsilon(t)_k, \varepsilon(t\text{-}1)_k, \varepsilon(t\text{-}2)_k, \varepsilon(t\text{-}3)_k, \ldots, \varepsilon(t\text{-}11)_k)',$$

the matrix of sample covariance terms as

$$\Omega = (\varepsilon_k\, \varepsilon_k') / K$$

where K is the total number of observations, and the *ij*th element of Ω as $\sigma_{ij} = \sigma_{ji}$. The *ij*th element of the sample correlation matrix is $r_{ij} = \sigma_{ij} / \sqrt{(\sigma_{ii}\, \sigma_{jj})}$.

The squared off diagonal elements in the correlation matrix are asymptotically distributed chi-square with one degree of freedom under the null hypothesis of no cross equation correlation. This statistic allows assessment of whether two individual models in the potential system have significant cross equation correlation. The summed squares of a column (or row) in the correlation matrix, without the diagonal element, is asymptotically distributed chi-square with degrees of freedom equal the number of models *n* the potential system less one. For the systems examined in here there are eleven degrees of freedom. This statistic allows assessment of whether an individual model has significant cross equation correlation with all other models in the potential system. The summed squares of all above (or below) diagonal elements in the correlation matrix is asymptotically distributed chi-square with degrees of freedom equal to half the number of equation in the potential system squared, less the number of equations in the system. For the systems examined here there are 66 degrees of freedom.

The following four tables present chi-squared statistics testing for cross-equation correlation in the live cattle and live hog futures price models using contemporaneous and incurred variable cost of feeding. Also presented are the significance levels of the test statistics. The results conclusively suggest cross equation correlation is present between most of the models of live cattle and live hog futures price systems.

Table C.1 Lagrange Multiplier Tests Examining Cross Equation Correlation in the Contemporaneous Cost Live Cattle Futures Price Models.

	FP(t)	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)
Statistic 1: Tests of Correlations between Individual Models												
FP(t)	—	45.4655 (0.0001)	13.7572 (0.0002)	5.9423 (0.0148)	5.2561 (0.0219)	4.1667 (0.0412)	3.7305 (0.0534)	1.3308 (0.2487)	3.0019 (0.0832)	5.7587 (0.0164)	2.7543 (0.0970)	2.3084 (0.1287)
FP(t-1)			31.8233 (0.0001)	16.4300 (0.0001)	9.2373 (0.0024)	10.6369 (0.0011)	11.4665 (0.0007)	7.6594 (0.0056)	8.4531 (0.0036)	9.2041 (0.0024)	5.9258 (0.0149)	3.9660 (0.0464)
FP(t-2)				33.2196 (0.0001)	7.8211 (0.0052)	6.0326 (0.0140)	15.9624 (0.0001)	12.2489 (0.0005)	7.7040 (0.0055)	1.4068 (0.2356)	2.3870 (0.1224)	5.8775 (0.0153)
FP(t-3)					33.7292 (0.0001)	15.5611 (0.0001)	15.9016 (0.0001)	24.3675 (0.0001)	22.3155 (0.0001)	11.4174 (0.0007)	9.5977 (0.0019)	8.8055 (0.0030)
FP(t-4)						28.3435 (0.0001)	13.3834 (0.0003)	15.6417 (0.0001)	20.2939 (0.0001)	12.7278 (0.0004)	6.3872 (0.0115)	2.1008 (0.1472)
FP(t-5)							33.9421 (0.0001)	20.8554 (0.0001)	17.8773 (0.0000)	21.2290 (0.0001)	15.7786 (0.0001)	7.2006 (0.0073)
FP(t-6)								30.6565 (0.0001)	19.1508 (0.0000)	13.2397 (0.0003)	8.4006 (0.0038)	5.6591 (0.0174)
FP(t-7)									51.1846 (0.0001)	24.0000 (0.0001)	14.6363 (0.0001)	15.5065 (0.0001)
FP(t-8)										39.3061 (0.0001)	24.8561 (0.0001)	19.5306 (0.0001)
FP(t-9)											51.2928 (0.0001)	23.6721 (0.0001)
FP(t-10)												41.8488 (0.0001)
Statistic 2: Tests of Correlations of Individual Models with All Other Models												
	93.4724 (0.0001)	160.2680 (0.0001)	138.2402 (0.0001)	197.2874 (0.0001)	154.9220 (0.0001)	181.6238 (0.0001)	171.4931 (0.0001)	218.0876 (0.0001)	233.6738 (0.0001)	215.2544 (0.0001)	183.8651 (0.0001)	138.4759 (0.0001)
Statistic 3: The Test for Correlation within the Whole System												
	1043.3318 (0.0001)											

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[a] Statistic 1 is distributed $\chi^2(1)$, Statistic 2 is distributed$\chi^2(11)$, and Statistic 3 is distributed $\chi^2(66)$ under the null of no cross equation correlation.

Table C.2 Lagrange Multiplier Tests Examining Cross Equation Correlation in the Incurred Cost Live Cattle Futures Price Models.

	FP(t)	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)
Statistic 1: Tests of Correlations between Individual Models												
FP(t)	—	56.6011	21.4663	6.0809	0.0308	0.1041	0.0996	0.2313	0.0001	0.0121	0.0003	0.5485
		(0.0001)	(0.0001)	(0.0137)	(0.8607)	(0.7469)	(0.7523)	(0.6306)	(0.9926)	(0.9124)	(0.9866)	(0.4589)
FP(t-1)			43.3788	19.7442	1.9201	0.0002	1.3664	0.0771	0.3721	0.0026	0.1122	0.2327
			(0.0001)	(0.0001)	(0.1658)	(0.9888)	(0.2424)	(0.7813)	(0.5419)	(0.9597)	(0.7377)	(0.6296)
FP(t-2)				42.9395	8.5970	0.0000	5.7542	2.1003	0.4309	0.4967	0.2590	0.0107
				(0.0001)	(0.0034)	(0.9972)	(0.0165)	(0.1473)	(0.5115)	(0.4810)	(0.6108)	(0.9177)
FP(t-3)					27.2435	1.1301	5.9945	9.7650	8.0900	1.0054	1.0863	0.7672
					(0.0001)	(0.2878)	(0.0144)	(0.0018)	(0.0045)	(0.3160)	(0.2973)	(0.3811)
FP(t-4)						11.1680	10.8705	11.9458	18.3218	7.3445	1.4690	0.5410
						(0.0008)	(0.0010)	(0.0005)	(0.0000)	(0.0067)	(0.2255)	(0.4620)
FP(t-5)							33.9396	20.5842	17.8793	21.2348	15.7740	7.2131
							(0.0001)	(0.0001)	(0.0000)	(0.0001)	(0.0001)	(0.0072)
FP(t-6)								30.6565	19.1508	13.2397	8.4006	5.6591
								(0.0001)	(0.0000)	(0.0003)	(0.0038)	(0.0174)
FP(t-7)									51.1846	24.0000	14.6363	15.5065
									(0.0001)	(0.0001)	(0.0001)	(0.0001)
FP(t-8)										39.3061	24.8561	19.5306
										(0.0001)	(0.0001)	(0.0001)
FP(t-9)											51.2928	25.6721
											(0.0001)	(0.0001)
FP(t-10)												41.8488
												(0.0001)
Statistic 2: Tests of Correlations of Individual Models with All Other Models												
	85.1751	123.8072	125.4334	123.8468	99.4520	129.2973	135.1316	180.9575	199.1223	183.6068	159.7354	117.5302
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Statistic 3: The Test for Correlation within the Whole System												
	831.5477											
	(0.0001)											

[a] Statistic 1 is distributed $\chi^2(1)$, Statistic 2 is distributed$\chi^2(11)$, and Statistic 3 is distributed $\chi^2(66)$ under the null of no cross equation correlation.

Table C.3 Lagrange Multiplier Tests Examining Cross Equation Correlation in the Contemporaneous Cost Live Hog Futures Price Models.

	FP(t)	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)
Statistic 1: Tests of Correlations between Individual Models												
FP(t)	—	34.9391	10.1119	1.6480	1.4866	7.2229	5.5727	8.3453	4.2382	3.0358	2.7245	0.5734
		(0.0001)	(0.0015)	(0.1992)	(0.2227)	(0.0072)	(0.0182)	(0.0039)	(0.0395)	(0.0814)	(0.0988)	(0.4489)
FP(t-1)			16.4210	4.3020	1.0274	4.9270	7.0201	4.9376	3.7478	0.6892	0.7008	0.2688
			(0.0001)	(0.0381)	(0.3108)	(0.0264)	(0.0081)	(0.0263)	(0.0529)	(0.4064)	(0.4025)	(0.6041)
FP(t-2)				18.4810	0.1065	0.7750	0.9512	1.9555	0.0208	0.2708	0.1052	0.2701
				(0.0000)	(0.7442)	(0.3787)	(0.3294)	(0.1620)	(0.8853)	(0.6028)	(0.7457)	(0.6033)
FP(t-3)					18.8998	8.6193	5.5843	2.4340	3.4516	2.1729	3.2534	13.4045
					(0.0000)	(0.0033)	(0.0181)	(0.1187)	(0.0632)	(0.1405)	(0.0713)	(0.0003)
FP(t-4)						26.3603	11.5189	9.8353	6.5811	3.6315	7.7509	9.1645
						(0.0001)	(0.0007)	(0.0017)	(0.0103)	(0.0567)	(0.0054)	(0.0025)
FP(t-5)							42.8380	25.6731	28.0143	18.4460	22.0674	17.6100
							(0.0001)	(0.0001)	(0.0001)	(0.0000)	(0.0001)	(0.0000)
FP(t-6)								40.6870	35.2658	22.7248	24.0511	18.5048
								(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0000)
FP(t-7)									65.1134	53.3794	46.3451	37.1629
									(0.0001)	(0.0001)	(0.0001)	(0.0001)
FP(t-8)										68.7928	58.4809	43.8496
										(0.0001)	(0.0001)	(0.0001)
FP(t-9)											72.5074	59.2654
											(0.0001)	(0.0001)
FP(t-10)												68.0886
												(0.0001)
Statistic 2: Tests of Correlations of Individual Models with All Other Models												
	79.8985	78.9808	49.4690	82.2509	96.3628	202.5534	214.7188	295.8685	317.5563	304.9161	306.0753	268.1626
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Statistic 3: The Test for Correlations within the Whole System												
	1148.4065											
	(0.0001)											

[a] Statistic 1 is distributed $\chi^2(1)$, Statistic 2 is distributed $\chi^2(11)$, and Statistic 3 is distributed $\chi^2(66)$ under the null of no cross equation correlation.

Table C.4 Lagrange Multiplier Tests Examining Cross Equation Correlation in the Incurred Cost Live Hog Futures Price Models.

	FP(t)	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)
Statistic 1: Tests of Correlations between Individual Models												
FP(t)	—	71.0324 (0.0001)	42.9910 (0.0001)	16.0068 (0.0001)	1.3099 (0.2524)	0.9497 (0.3298)	0.0181 (0.8931)	0.0900 (0.7642)	0.4397 (0.5073)	0.4165 (0.5187)	0.4604 (0.4974)	1.1821 (0.2769)
FP(t-1)			73.1810 (0.0001)	40.0253 (0.0001)	7.6475 (0.0057)	0.8242 (0.3640)	0.0638 (0.8005)	0.2242 (0.6359)	0.1822 (0.6695)	0.1112 (0.2918)	0.8205 (0.3650)	2.0951 (0.1478)
FP(t-2)				65.9757 (0.0001)	21.8065 (0.0001)	0.1251 (0.7235)	0.6624 (0.4157)	0.0022 (0.9624)	2.0462 (0.1526)	1.6745 (0.1957)	1.7618 (0.1844)	3.5406 (0.0599)
FP(t-3)					43.3229 (0.0001)	2.5033 (0.1136)	3.5046 (0.0612)	1.2198 (0.2694)	3.3787 (0.0660)	2.0059 (0.1567)	3.1195 (0.0774)	9.4473 (0.0021)
FP(t-4)						22.5582 (0.0001)	14.4395 (0.0001)	4.9583 (0.0260)	10.4517 (0.0012)	6.4295 (0.0112)	11.6469 (0.0006)	14.0896 (0.0002)
FP(t-5)							42.8380 (0.0001)	25.6731 (0.0001)	28.0143 (0.0001)	18.4460 (0.0000)	22.0674 (0.0001)	17.6100 (0.0000)
FP(t-6)								40.6870 (0.0001)	35.2658 (0.0001)	22.7248 (0.0001)	24.0511 (0.0001)	18.5048 (0.0000)
FP(t-7)									65.1134 (0.0001)	53.3794 (0.0001)	46.3451 (0.0001)	37.1629 (0.0001)
FP(t-8)										68.7928 (0.0001)	58.4809 (0.0001)	43.8496 (0.0001)
FP(t-9)											72.5074 (0.0001)	59.2654 (0.0001)
FP(t-10)												68.0886 (0.0001)
Statistic 2: Tests of Correlations of Individual Models with All Other Models												
	134.8965 (0.0001)	197.2072 (0.0001)	213.7672 (0.0001)	190.5097 (0.0001)	158.6601 (0.0001)	181.6093 (0.0001)	202.7600 (0.0001)	247.8553 (0.0001)	316.0152 (0.0001)	306.7535 (0.0001)	309.3495 (0.0001)	274.8359 (0.0001)
Statistic 3: The Test for Correlation within the Whole System												
	1380.6099 (0.0001)											

[a] Statistic 1 is distributed $\chi^2(1)$, Statistic 2 is distributed$\chi^2(11)$, and Statistic 3 is distributed $\chi^2(66)$ under the null of no cross equation correlation.

Appendix D

The following tabies contain complete parametric results for all models. Table D.1 presents results for the live cattle futures price models incorporating contemporaneous variable costs feeding. Table D.2 presents results for the live hog futures price models incorporating contemporaneous costs of feeding. Table D.3 presents live cattle model results incorporating incurred variable costs of feeding. Table D.4 presents live hog model results incorporating incurred variable costs of feeding.

Table D.1. Parameter Estimates, Standard Errors, and Other Information from Iterated Seemly Unrelated Regressions Corrected for Serial Correlation of Contemporaneous USDA Great Plains Variable Cattle Feeding Costs on Live Cattle Futures Prices.

Dependent Variable Independent Variable	FP(t) VC(t)	FP(t-1) VC(t-1)	FP(t-2) VC(t-2)	FP(t-3) VC(t-3)
	Parameter Estimates and Standard Errors			
Intercept	-3.4206 (4.3236)	-3.8409 (2.7329)	-1.2135 (3.3899)	0.3810 (2.4891)
Variable Costs	1.0576 (0.0674)	1.0539 (0.0428)	1.0298 (0.0546)	1.0199 (0.0407)
April	3.9090 (1.1170)	2.8508 (1.0057)	0.5674 (0.8507)	-1.0450 (0.7041)
June	2.9180 (1.3286)	4.7356 (1.1222)	2.2051 (1.0210)	0.4742 (0.8389)
August	0.5087 (1.3600)	0.9321 (1.1244)	0.3765 (1.0487)	0.5258 (0.8504)
October	2.0921 (1.3203)	2.4373 (1.1061)	-0.5006 (1.0036)	-2.1074 (0.8188)
December	1.3808 (1.1139)	2.7036 (0.9943)	2.6368 (0.8389)	1.1025 (0.6939)
ρ	0.4368 (0.0777)	0.2516 (0.0765)	0.5197 (0.0757)	0.4404 (0.0746)
Error Variance	11.7745	8.2337	7.1778	4.6447
R-Square	0.8946	0.9228	0.9316	0.9556
Observations	73	73	73	73

Table D.1 (continued). Parameter Estimates, Standard Errors, and Other Information from Iterated Seemly Unrelated Regressions Corrected for Serial Correlation of Contemporaneous USDA Great Plains Variable Cattle Feeding Costs on Live Cattle Futures Prices.

Dependent Variable Independent Variable	FP(t-4) VC(t-4)	FP(t-5) VC(t-5)	FP(t-6) VC(t-6)	FP(t-7) VC(t-7)
		Parameter Estimates and Standard Errors		
Intercept	2.8954 (1.4884)	1.5039 (1.4156)	1.7117 (1.9476)	2.3548 (1.8050)
Variable Costs	1.0127 (0.0235)	1.0180 (0.0224)	0.9907 (0.0316)	0.9819 (0.0291)
April	-1.3975 (0.8865)	-0.0496 (0.8007)	2.5029 (0.6990)	2.1946 (0.6175)
June	-1.2108 (0.8744)	-1.4664 (0.8007)	1.0016 (0.7913)	1.8935 (0.7124)
August	-2.0495 (0.8559)	-1.9764 (0.7860)	-0.6966 (0.7986)	-0.9689 (0.7218)
October	-2.8669 (0.8542)	-1.7236 (0.7849)	-1.8398 (0.7793)	-1.7386 (0.7024)
December	-1.9169 (0.8701)	-1.9210 (0.7871)	-0.0633 (0.6904)	0.3275 (0.6108)
ρ	-0.0369 (0.0745)	-0.0051 (0.0728)	0.2901 (0.0804)	0.3473 (0.0708)
Error Variance	4.9110	4.1450	4.1054	3.3530
R-Square	0.9521	0.9600	0.9587	0.9675
Observations	73	73	73	73

Table D.1 (continued). Parameter Estimates, Standard Errors, and Other Information from Iterated Seemly Unrelated Regressions Corrected for Serial Correlation of Contemporaneous USDA Great Plains Variable Cattle Feeding Costs on Live Cattle Futures Prices.

Dependent Variable Independent Variable	FP(t-8) VC(t-8)	FP(t-9) VC(t-9)	FP(t-10) VC(t-10)	FP(t-11) VC(t-11)
	Parameter Estimates and Standard Errors			
Intercept	4.0515 (1.5628)	4.4204 (1.6529)	4.1200 (1.7834)	5.1695 (2.3037)
Variable Costs	0.9599 (0.0251)	0.9595 (0.0261)	0.9418 (0.0284)	0.9213 (0.0370)
April	0.4247 (0.7189)	0.1864 (0.8066)	1.7095 (0.6952)	2.0548 (0.6631)
June	2.7017 (0.7735)	2.1053 (0.8546)	2.1754 (0.7731)	2.4908 (0.7785)
August	-0.3872 (0.7669)	0.0075 (0.8448)	2.4465 (0.7764)	2.7088 (0.7975)
October	-2.2875 (0.7619)	-2.7988 (0.8392)	-0.3616 (0.7602)	0.6932 (0.7707)
December	-1.1119 (0.7097)	-1.5973 (0.7952)	-0.4038 (0.6858)	-0.2721 (0.6562)
ρ	0.1583 (0.0707)	0.1222 (0.0683)	0.2420 (0.0715)	0.4043 (0.0795)
Error Variance	3.894	4.7479	3.8992	4.0359
R-Square	0.9606	0.9543	0.9611	0.9607
Observations	73	73	73	73

Table D.2. Parameter Estimates, Standard Errors, and Other Information from Iterated Seemly Unrelated Regressions Corrected for Serial Correlation of Contemporaneous USDA Corn Belt Variable Hog Feeding Costs on Live Hog Futures Prices.

Dependent Variable	FP(t)	FP(t-1)	FP(t-2)	FP(t-3)
Independent Variable	VC(t)	VC(t-1)	VC(t-2)	VC(t-3)
	Parameter Estimates and Standard Errors			
Intercept	-2.5546	-2.9341	-1.6668	3.1354
	(4.8778)	(2.7469)	(2.0857)	(1.9753)
Variable Costs	1.3164	1.3099	1.3700	1.1816
	(0.1081)	(0.0670)	(0.0534)	(0.0504)
Trend	-5.7270	-7.8731	-7.6211	-4.1292
	(1.1144)	(1.4703)	(1.1177)	(0.8898)
Quadratic Trend	4.3084	-1.2409	-6.7599	-5.1083
	(1.2655)	(1.3206)	(1.0512)	(0.9283)
Cubic Trend	5.8933	2.0391	-3.3680	-3.8988
	(1.3142)	(1.3081)	(1.0216)	(0.9149)
April	2.9011	1.3248	-2.4720	-3.1538
	(1.3129)	(1.3224)	(1.0179)	(0.9049)
June	1.8689	-2.0097	-6.4032	-3.7145
	(1.2946)	(1.3049)	(1.0125)	(0.8870)
July	4.2369	0.9443	-2.4526	-2.8441
	(1.1491)	(1.4116)	(1.0699)	(0.8732)
August	-0.2736	-0.0733	-0.1286	-0.1165
	(0.2736)	(0.1003)	(0.0793)	(0.0822)
October	0.0059	0.0026	0.0034	0.0045
	(0.0038)	(0.0021)	(0.0017)	(0.0017)
December	-0.0000	-0.0000	-0.0000	-0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
ρ	0.3554	-0.1653	-0.1383	0.0278
	(0.0814)	(0.0857)	(0.0871)	(0.0760)
Error Variance	11.4883	12.2818	7.2683	5.6384
R-Square	0.7869	0.7690	0.8689	0.8844
Observations	93	93	93	93

Table D.2 (continued). Parameter Estimates, Standard Errors, and Other Information from Iterated Seemly Unrelated Regressions Corrected for Serial Correlation of Contemporaneous USDA Corn Belt Variable Hog Feeding Costs on Live Hog Futures Prices.

Dependent Variable	FP(t-4)	FP(t-5)	FP(t-6)	FP(t-7)
Independent Variable	VC(t-4)	VC(t-5)	VC(t-6)	VC(t-7)
	Parameter Estimates and Standard Errors			
Intercept	0.2669	5.9249	2.6020	6.1845
	(2.2099)	(2.3675)	(2.2622)	(2.1032)
Variable Costs	1.2626	1.0448	1.1641	1.0596
	(0.0562)	(0.0567)	(0.0511)	(0.0440)
Trend	-1.2889	-0.3569	0.2503	-1.9169
	(0.9642)	(0.7555)	(1.2882)	(1.6507)
Quadratic Trend	-2.3039	1.1798	3.8567	3.1957
	(0.9605)	(0.8183)	(1.1631)	(1.3456)
Cubic Trend	-3.6839	0.5439	3.0032	3.3931
	(0.9632)	(0.8300)	(1.1575)	(1.4144)
April	-4.9057	-3.0971	-0.1508	0.7034
	(0.9750)	(0.8492)	(1.1712)	(1.4236)
June	-3.6653	-3.6075	-4.3772	-5.2647
	(0.9437)	(0.8204)	(1.1619)	(1.3522)
July	-3.0207	-0.2609	0.3195	-2.0123
	(0.9436)	(0.7333)	(1.2492)	(1.6045)
August	-0.1650	-0.1666	-0.3083	-0.2605
	(0.0841)	(0.1003)	(0.0882)	(0.0901)
October	0.0050	0.0060	0.0084	0.0080
	(0.0018)	(0.0021)	(0.0019)	(0.0019)
December	-0.0000	-0.0000	-0.0001	-0.0001
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
ρ	-0.0113	0.2523	-0.1679	-0.3245
	(0.0829)	(0.0722)	(0.0794)	(0.0647)
Error Variance	6.4204	4.8409	9.5759	12.9542
R-Square	2.5339	2.2002	3.0945	3.5992
Observations	93	93	93	93

Table D.2 (continued). Parameter Estimates, Standard Errors, and Other Information from Iterated Seemly Unrelated Regressions Corrected for Serial Correlation of Contemporaneous USDA Corn Belt Variable Hog Feeding Costs on Live Hog Futures Prices.

Dependent Variable Independent Variable	FP(t-8) VC(t-8)	FP(t-9) VC(t-9)	FP(t-10) VC(t-10)	FP(t-11) VC(t-11)
	Parameter Estimates and Standard Errors			
Intercept	6.7190	10.2492	11.1116	13.3564
	(2.3904)	(2.5263)	(3.0604)	(3.6348)
Variable Costs	1.0421	0.9033	0.8659	0.8056
	(0.0500)	(0.0526)	(0.0626)	(0.0695)
Trend	-1.5706	-0.0654	-0.3630	-0.7227
	(1.5328)	(1.0775)	(1.2257)	(0.8882)
Quadratic Trend	3.3526	3.1074	2.9545	3.9602
	(1.3847)	(1.1206)	(1.2906)	(1.0722)
Cubic Trend	4.8340	4.5668	3.5902	4.1147
	(1.3861)	(1.1161)	(1.2863)	(1.0959)
April	2.5661	3.7219	3.5619	2.9683
	(1.4006)	(1.1385)	(1.3162)	(1.1166)
June	-2.0502	0.3868	2.1660	2.7671
	(1.3835)	(1.1201)	(1.3141)	(1.1058)
July	-2.0464	-1.3628	1.3144	2.6794
	(1.5000)	(1.0537)	(1.1871)	(0.9032)
August	-0.3427	-0.3206	-0.3499	-0.3726
	(0.1060)	(0.1150)	(0.1375)	(0.1820)
October	0.0096	0.0099	0.0104	0.0107
	(0.0022)	(0.0024)	(0.0029)	(0.0038)
December	-0.0001	-0.0001	-0.0001	-0.0001
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
ρ	-0.1642	0.1211	0.1565	0.4604
	(0.0606)	(0.0553)	(0.0583)	(0.0558)
Error Variance	13.7482	9.0116	11.8197	8.0258
R-Square	0.6933	0.7714	0.7199	0.7927
Observations	93	93	93	93

Table D.3. Parameter Estimates, Standard Errors, and Other Information from Iterated Seemly Unrelated Regressions Corrected for Serial Correlation of Incurred USDA Great Plains Variable Cattle Feeding Costs on Live Cattle Futures Prices.

Dependent Variable Independent Variable	FP(t) VC(t-5)	FP(t-1) VC(t-5)	FP(t-2) VC(t-5)	FP(t-3) VC(t-5)
	Parameter Estimates and Standard Errors			
Intercept	95.3255	54.0726	7.4774	2.8263
	(20.4441)	(11.5709)	(3.5453)	(2.5387)
Variable Costs	-0.3550	0.1513	0.9029	0.9845
	(0.1854)	(0.1681)	(0.0575)	(0.0411)
April	2.8972	3.7138	2.6923	0.7838
	(1.1621)	(1.0707)	(1.4571)	(1.1525)
June	1.0752	3.8121	1.7474	1.3568
	(1.4996)	(1.3796)	(1.6084)	(1.2200)
August	-0.9084	-0.1493	-2.0817	-0.7320
	(1.6071)	(1.4760)	(1.6040)	(1.2048)
October	-0.8708	0.1901	-1.8170	-2.2215
	(1.4675)	(1.3495)	(1.5768)	(1.1956)
December	-0.4622	0.5674	0.3575	-0.2006
	(1.1807)	(1.0867)	(1.4401)	(1.1364)
ρ	0.9549	0.8863	0.2119	0.1130
	(0.0359)	(0.0504)	(0.0660)	(0.0714)
Error Variance	20.2854	16.0971	16.7513	9.6109
R-Square	0.8185	0.8491	0.8404	0.9080
Observations	73	73	73	73

Table D.3 (continued). Parameter Estimates, Standard Errors, and Other Information from Iterated Seemly Unrelated Regressions Corrected for Serial Correlation of Incurred USDA Great Plains Variable Cattle Feeding Costs on Live Cattle Futures Prices.

Dependent Variable Independent Variable	FP(t-4) VC(t-5)	FP(t-5) VC(t-5)	FP(t-6) VC(t-6)	FP(t-7) VC(t-6)
	Parameter Estimates and Standard Errors			
Intercept	2.6401 (2.4658)	1.1813 (1.5510)	1.8533 (2.0111)	1.6303 (1.8108)
Variable Costs	0.9984 (0.0404)	1.0234 (0.0250)	0.9883 (0.0328)	0.9943 (0.0293)
April	-0.2410 (0.8468)	-0.0396 (0.7031)	2.5008 (0.6988)	2.2054 (0.6322)
June	0.2408 (0.9672)	-1.4664 (0.7500)	1.0031 (0.7913)	1.8989 (0.7198)
August	-2.0859 (0.9750)	-1.9771 (0.7415)	-0.6915 (0.7989)	-0.9883 (0.7259)
October	-3.0356 (0.9483)	-1.7179 (0.7351)	-1.8363 (0.7794)	-1.7659 (0.7093)
December	-2.0197 (0.8392)	-1.9165 (0.6934)	-0.0622 (0.6902)	0.3152 (0.6248)
ρ	0.3011 (0.0823)	0.1308 (0.0843)	0.2912 (0.0824)	0.3069 (0.0752)
Error Variance	6.0884	3.6346	4.1056	3.4033
R-Square	0.9406	0.9650	0.9587	0.9670
Observations	73	73	73	73

Table D.3 (continued). Parameter Estimates, Standard Errors, and Other Information from Iterated Seemly Unrelated Regressions Corrected for Serial Correlation of Incurred USDA Great Plains Variable Cattle Feeding Costs on Live Cattle Futures Prices.

Dependent Variable Independent Variable	FP(t-8) VC(t-8)	FP(t-9) VC(t-9)	FP(t-10) VC(t-10)	FP(t-11) VC(t-11)
	Parameter Estimates and Standard Errors			
Intercept	3.0238	3.3536	2.9099	3.6874
	(1.5369)	(1.6152)	(1.6960)	(2.1206)
Variable Costs	0.9776	0.9775	0.9622	0.9460
	(0.0246)	(0.0254)	(0.0269)	(0.0339)
April	0.4210	0.1942	1.7372	2.0843
	(0.7425)	(0.8698)	(0.7257)	(0.6857)
June	2.7103	2.2176	2.1977	2.5198
	(0.7821)	(0.8836)	(0.7868)	(0.7896)
August	-0.4011	0.0327	2.4863	2.7473
	(0.7720)	(0.8687)	(0.7844)	(0.8030)
October	-2.3299	-2.7997	-0.3410	0.7366
	(0.7701)	(0.8676)	(0.7733)	(0.7807)
December	-1.1444	-1.6178	-0.4242	-0.2672
	(0.7321)	(0.8557)	(0.7150)	(0.6778)
ρ	0.1096	0.0317	0.1779	0.3403
	(0.0714)	(0.0711)	(0.0700)	(0.0782)
Error Variance	3.9769	5.0729	4.0272	4.1061
R-Square	0.9598	0.9512	0.9598	0.9600
Observations	73	73	73	73

Table D.4. Parameter Estimates, Standard Errors, and Other Information from Iterated Seemly Unrelated Regressions Corrected for Serial Correlation of Incurred USDA Corn Belt Variable Hog Feeding Costs on Live Hog Futures Prices.

Dependent Variable Independent Variable	FP(t) VC(t-5)	FP(t-1) VC(t-5)	FP(t-2) VC(t-5)	FP(t-3) VC(t-5)
	Parameter Estimates and Standard Errors			
Intercept	41.4942 (6.7244)	21.4550 (5.8497)	13.4122 (5.6478)	7.4125 (4.4949)
Variable Costs	0.1969 (0.1654)	0.5899 (0.1482)	0.8410 (0.1442)	0.9605 (0.1156)
Trend	-2.8853 (1.7387)	-1.5533 (2.3897)	-0.3907 (2.3078)	0.3261 (1.6246)
Quadratic Trend	2.3420 (1.9030)	2.6210 (2.2928)	1.2672 (2.1963)	1.9186 (1.6031)
Cubic Trend	2.3903 (1.9607)	1.3334 (2.2721)	0.3455 (2.1781)	1.0444 (1.5915)
April	0.3475 (2.0168)	-0.4267 (2.3215)	-2.4652 (2.2265)	-1.2328 (1.6313)
June	-2.2695 (1.9161)	-1.7942 (2.2941)	-4.2759 (2.1979)	-3.0838 (1.6065)
July	-0.1436 (1.6739)	-0.4084 (2.3044)	-0.0500 (2.2244)	1.0063 (1.5650)
August	-0.3626 (0.2564)	-0.0106 (0.1997)	-0.3181 (1.1883)	-0.0513 (0.1492)
October	0.0097 (0.0053)	0.0027 (0.0042)	0.0026 (0.0040)	0.0037 (0.0031)
December	-0.0001 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)
ρ	0.3124 (0.0671)	-0.0323 (0.0649)	-0.0480 (0.0644)	0.0312 (0.0720)
Error Variance	26.3264	37.7565	34.6408	18.4722
R-Square	0.5116	0.2899	0.3750	0.6212
Observations	93	93	93	93

Table D.4 (continued). Parameter Estimates, Standard Errors, and Other Information from Iterated Seemly Unrelated Regressions Corrected for Serial Correlation of Incurred USDA Corn Belt Variable Hog Feeding Costs on Live Hog Futures Prices.

Dependent Variable Independent Variable	FP(t-4) VC(t-5)	FP(t-5) VC(t-5)	FP(t-6) VC(t-6)	FP(t-7) VC(t-6)
	Parameter Estimates and Standard Errors			
Intercept	2.0209	4.4334	2.1093	7.1221
	(3.7134)	(2.4179)	(2.2762)	(2.1365)
Variable Costs	1.1605	1.0894	1.1771	1.0324
	(0.0947)	(0.0589)	(0.0516)	(0.0461)
Trend	0.6402	-0.2450	0.3247	-1.9549
	(1.1247)	(0.7573)	(1.3482)	(1.5031)
Quadratic Trend	2.0811	1.2065	3.9267	3.1100
	(1.1864)	(0.8161)	(1.1858)	(1.2871)
Cubic Trend	0.0210	0.4805	3.0450	3.3229
	(1.1953)	(0.8270)	(1.1924)	(1.3154)
April	-2.4280	-3.2176	-0.1333	0.6890
	(1.2304)	(0.8470)	(1.2055)	(1.3268)
June	-4.1141	-3.6663	-4.3716	-5.2159
	(1.1911)	(0.8184)	(1.1851)	(1.2939)
July	0.0554	-0.2136	0.3808	-2.0045
	(1.0842)	(0.7340)	(1.3061)	(1.4626)
August	-0.1520	-0.1731	-0.3097	-0.2573
	(0.1350)	(0.0986)	(0.0867)	(0.0914)
October	0.0051	0.0060	0.0084	0.0080
	(0.0028)	(0.0021)	(0.0018)	(0.0019)
December	-0.0000	-0.0000	-0.0001	-0.0001
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
ρ	0.1983	0.2421	-0.2105	-0.2513
	(0.0777)	(0.0748)	(0.0805)	(0.0648)
Error Variance	10.1588	4.8110	9.9584	11.8547
R-Square	0.7983	0.8841	0.7852	0.7115
Observations	93	93	93	93

Table D.4 (continued). Parameter Estimates, Standard Errors, and Other Information from Iterated Seemly Unrelated Regressions Corrected for Serial Correlation of Incurred USDA Corn Belt Variable Hog Feeding Costs on Live Hog Futures Prices.

Dependent Variable Independent Variable	FP(t-8) VC(t-8)	FP(t-9) VC(t-9)	FP(t-10) VC(t-10)	FP(t-11) VC(t-11)
	Parameter Estimates and Standard Errors			
Intercept	6.1346	10.4894	10.8009	13.4052
	(2.3758)	(2.4799)	(3.0195)	(3.6551)
Variable Costs	1.0587	0.8962	0.8742	0.8044
	(0.0492)	(0.0513)	(0.0614)	(0.0699)
Trend	-1.5584	-0.0658	-0.3282	-0.7244
	(1.6048)	(1.1319)	(1.2635)	(0.8850)
Quadratic Trend	3.3927	3.1423	3.0009	3.9555
	(1.4176)	(1.1559)	(1.3164)	(1.0699)
Cubic Trend	4.8744	4.5725	3.6290	4.1125
	(1.4308)	(1.1463)	(1.3078)	(1.0938)
April	2.5918	3.6993	3.5962	2.9677
	(1.4450)	(1.1685)	(1.3374)	(1.1144)
June	-2.0597	0.3897	2.2139	2.7636
	(1.4165)	(1.1546)	(1.3380)	(1.1038)
July	-2.0772	-1.3164	1.3442	2.6754
	(1.5683)	(1.1056)	(1.2241)	(0.9006)
August	-0.3436	-0.3210	-0.3514	-0.3727
	(0.1050)	(0.1128)	(0.1357)	(0.1829)
October	0.0096	0.0099	0.0104	0.0107
	(0.0022)	(0.0024)	(0.0028)	(0.0038)
December	-0.0001	-0.0001	-0.0001	-0.0001
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
ρ	-0.2013	0.0787	0.1297	0.4641
	(0.0610)	(0.0558)	(0.0581)	(0.0556)
Error Variance	14.4125	9.5793	12.3024	7.9888
R-Square	0.6785	0.7570	0.7084	0.7936
Observations	93	93	93	93

Appendix E

A unique test is used to compare the size of the error variances in the seemingly unrelated regression systems. Typically, comparing the relative size of two variances from two random variables involves taking the ratio of the sample variances and using a F-test. However, the F-test requires the random variables in question to be independent. The error terms of the futures price / variable feeding cost systems are not independent. A procedure is used which was developed by Pitman (Cox and Hinkley, pp. 140-1).

In model notation, any two error terms in the system are distributed normally with variances $Var(\varepsilon(t\text{-}i)_k) = \sigma_i^2$ and $Var(\varepsilon(t\text{-}j)_k) = \sigma_j^2$, and covariance $Cov(\varepsilon(t\text{-}i)_k), (\varepsilon(t\text{-}j)_k) = \sigma_{ij}$. To test the hypothesis $\sigma_i^2 < \sigma_j^2$, the two original random error terms are transformed into two alternative random variables, $v_k = \varepsilon(t\text{-}i)_k + \varepsilon(t\text{-}j)_k$ and $w_k = \varepsilon\ (t\text{-}i)_k - \varepsilon(t\text{-}j)_k$. Sample correlations of the transformed random variables are constructed

$$r_{ij} = \Sigma v_k w_k / \sqrt{} (\Sigma v_k^2\ \Sigma w_k^2)$$

and the following statistic

$$t_{ij} = r_{ij} \sqrt{} (K\text{-}1) / \sqrt{} (1 - r_{ij}^2)$$

has a t-distribution with degrees of freedom equal to the sample size less one under the null hypothesis of equivalent variance. A one-sided t-test is performed. Test results are reported in tables 1 and 2.

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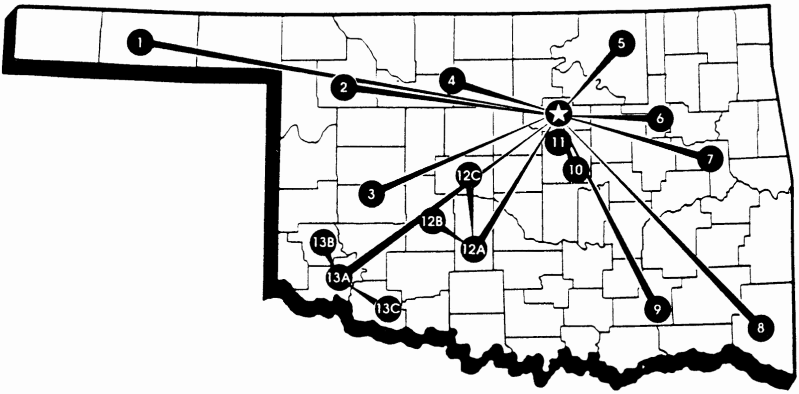

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