Design and Evaluation of Long Term Commodity Pricing Contracts

by

James Unterschultz, Frank Novak, and Stephen Koontz

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Abstract

Window contracts and cost plus contracts are being used for managing risk in long term producer-processor contracting relationships. Window contracts place a floor price and a ceiling price on the value of the commodity to the producer. Cost plus contacts base the minimum price on the cost of inputs. These contracts can be decomposed into portfolios of specialized put and call options. Monte Carlo option valuation techniques evaluated the impact of different price process assumptions on the values in these contracts. The conclusions are that knowledge of the price process is very important. Mean reverting processes, where the mean is correctly identified, lead to lower valued implied options in both window and spread contracts. Different strike prices are required for different times to maturity if the value of floor price (put option) is to equal the value of the ceiling price (call option) for window contracts. The floor and ceiling prices for window contracts and the cost plus portion of spread contracts need to change with the expected delivery date. A contract covering 10 years of production cannot have one single set of window prices or spread cost plus components.

Introduction

Commodity pricing contracts are being used for managing risk in long term producer-processor contracting relationships. Two types of over-the-counter long-term contracts identified by Lawrence and Wang (1997) are cost-plus and window contracts. A cost-plus contract bases the minimum price on a standardized cost of production and factors that influence costs such as feed prices. A window contract establishes a price floor and ceiling for the duration of the contract. The terms of these contracts vary from three to ten years. Shorter term contracts are available (Unterschultz et al. 1997) however this project focuses on long term contracts.

Various reasons may exist for long term contracting between a processor and a supplier. These might include:

- Processor has easier access to capital markets (equity or debt) than the smaller supplier. Processor removes uncertainty of supply.
- Processor and producer remove some price or margin risk.
- Processor ties other quality specifications into a long term contracting relationship. Supplier is more risk averse than processor.

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The valuation of these contracts needs to be critically evaluated to minimize the need for ad hoc adjustments (Lawrence and Wang, 1997). These ad hoc adjustments may be of sufficient size to bankrupt one of the parties. Second, sound valuation techniques will provide information on the viability of these contracts in the future. Huge implicit benefits favouring one party at the expense of the other party will destroy the potential usefulness of these contracts in the future. If these contracts can be valued and demonstrated to be useful to both the producer and processor then it may be possible to develop a secondary over-the-counter market for written contracts. The primary objective of this project is to evaluate the pricing and viability of long term contracts for risk management in agriculture commodities.

The paper has the following steps. First, cost-plus and windows contracts are explained in more detail. Finance theory, in particular option pricing, is used to decompose these contracts into portfolios of specialized calls and puts. Conceptually this provides a method for valuing long term commodity contingent claims. The finance literature is already addressing this valuation issue for non-agricultural commodities (Schwartz, 1997, Gibson and Schwartz 1990, 1991). Next, a critical component in valuing long term commodity contingent claims, the specification of the price distributions, are analyzed. The type of distribution or the existence of price reversion (Irwin, Zulauf and Jackson 1996; Schwartz 1997) has a major impact on the pricing and viability of any long-term window contracts. A random walk and a mean reverting price process for live cattle, feeder cattle, lean hogs, corn and soybean meal prices are evaluated. The roles of convenience yield and market volatility, while potentially extremely important, are not explored here. Option valuation theory will be combined with the price distributions to give valuation examples of cost-plus and window contracts for lean hogs and live cattle. Comments on the usefulness and viability of these contracts conclude the paper.

Background and Theory

Two types of long term contracts are examined. These are cost-plus contracts and window contracts. Lawrence and Wang (1997) discuss various versions of cost-plus contracts for the pork industry. Generally the minimum price is tied to the feed costs, typically corn and soybean meal prices. The minimum price rises as feed costs rise and declines as feed prices drop. The processor makes up the difference when market livestock prices are below the minimum price. The hog producer often makes up the price difference when market prices rise by some fixed amount over the minimum contract price. Often the feed prices are averaged over part of the production period for the hogs marketed on that contract. Ad hoc adjustments to the contract are often included in the contract to prevent one party benefiting tremendously to the detriment of the other party. For example, if one party has accrued a large dollar surplus by the end of the contracting period as a result of the contract, the counter party may elect to extend the contract period. As discussed later, the cost-plus contract is essentially a contract on producer margins or spreads, the difference between the input costs and the output price. These contracts manage the risk between changes in input and output prices.

Window contracts provide a minimum floor price and a maximum ceiling price to the producer. Price risk between the floor price and the ceiling price is accepted by the producer.

Conceptually, the producer removes price risk below the window floor in exchange for giving up price gains above the window ceiling. Conversely, the provider of the contract, often a processor or marketing organization, foregoes the possibility of purchasing commodities below the floor price in exchange for removing purchase prices above the window ceiling. Many different risk-sharing agreements are possible with a window contract or with a cost-plus contract. As also discussed below, window contracts are strictly a contract on the market price and only manage the output price risk from the producer perspective or the input price risk from the processor perspective.

Conceptually both window contracts and cost-plus contracts can be decomposed into portfolios of options. Windows contracts are the simpler of the two products to explain using finance terminology. Thus the discussion starts with window contracts.

A window contract, from the producer perspective, is a combination of a long put and a short call on the market output price. The long put strike price provides the floor market price. The processor sells this put to the farm. The short call strike price provides a ceiling market price. The farm sells this call to the processor. Algebraically the producer pay off at delivery of the finished product for production period extending from time t to T with a window contract is described as:

$$Farm\ Payoff_{t,T} = S_T + Max[X_L - S_T, 0] - Max[S_T - X_U, 0] \qquad (1)$$

where S_T is the market price at delivery, X_L is the fixed floor price and X_U is the fixed ceiling price where usually $X_L < X_U$. $Max[X_L - S_T, 0]$ is the terminal put payoff to the producer and $Max[S_T - X_U, 0]$ is the terminal call payoff to the processor. If the market price is below the floor price ($S_T<X_L$) at delivery the producer price is S_T plus the maximum of $X_L - S_T$ or 0. Thus, the pay off is $S_T + X_L - S_T$ which means the farm gets the floor price X_L. Similarly if $S_T>X_U$ then the farm payoff is the ceiling price X_U. If $X_L < S_T < X_U$ then the farm receives the prevailing market price, S_T.

The window contract can be designed to have zero value at the beginning of the contract by selecting a call strike price, and therefore the premium received, that equals the put premium paid. Further, to have a valid price window, the put strike price, X_L, must be less than the call strike, X_U. Notice that the ceiling and floor prices are fixed (non-stochastic) and that the window contract is only concerned with the market price of the commodity being sold by the supplier. The cost of production is not included in the contract and if there is a significant change in the cost of production, this is not covered by the window contract. Conceivably, the breakeven cost of production price could be well outside the price window established at the beginning of the contract. As discussed by Unterschultz et al. (1997), placing the window around or above the break even price may not allow the contract to be rationally valued when the break even is above prevailing futures market prices. Since early exercise of the window contract is not available prior to delivery, the options are European. Window contract valuation issues are discussed later in the paper.

Cost-plus contracts, or margin/spread contracts to be more exact, can also be decomposed into portfolios of specialized puts and calls and eliminate problems with determining the location of the window on window contracts. For simplification we assume here that the cost-plus contract has an upper bound beyond which the processor does not have to pay the market price. Without an upper bound, the processor has a large liability with no direct offsetting benefit. The options to be discussed next are related to exchange or spread options, the ability to exchange one asset for another asset. (Margrabe 1978, Shimko 1994). Shimko (1994) describes spread options as an option on a portfolio that is long one asset and short another.

With the cost-plus price contract the producer buys a spread put and sells a spread call. These spread options are based on the difference between input market prices such as soybean meal and corn, and output market prices. Analytically, the terminal farm payoff appears similar to the window contract (equation 1) but has several major differences in the definition of the terms. The analytical terminal payoff for production period from time t to T is:

$$Farm\ Payoff_{t,T} = S_T + Max[K^I_{L,t} - S_T, 0] - Max[S_T - (K^I_{L,t} + C), 0] \qquad (2)$$

where S_T is the market output price at delivery, $K^I_{L,t}$ is the minimum non-fixed floor price and C is some fixed dollar amount agreed to in the contract. $K^I_{L,t}$ is stochastic since it is a function of input prices and varies with time. For example, following Lawrence and Wang (1997) $K^I_{L,t}$ is calculated as a function of average corn prices and soybean meal prices during part of the production period[1]. The fixed constant C limits the liability of the processor offering such contracts. $Max[K^I_{L,t} - S_T, 0]$ is the terminal spread put payoff to the producer and $Max[S_T - (K^I_{L,t} + C), 0]$ is the terminal spread call payoff to the processor. If the market price is below the floor price $S_T < K^I_{L,t}$ at delivery the producer price is S_T plus the maximum of $K^I_{L,t} - S_T$ or 0. Thus, the pay off is $S_T + K^I_{L,t} - S_T$ which means the farm gets the minimum price, $K^I_{L,t}$ which is a function of production costs. Similarly if $S_T > K^I_{L,t} + C$ then the farm payoff is the ceiling price $K^I_{L,t} + C$ which is a function of production costs and some fixed amount above the fixed price. If $K^I_{L,t} < S_T < K^I_{L,t} + C$ then the farm receives the prevailing market price, S_T. Again, these options are not exercised until maturity, making them European.

Window contracts and cost plus contracts can be decomposed into portfolios of puts and calls. In theory these puts and calls can be valued. However, several valuation constraints exist with long-term contracts that are lessor issues with short-term contracts. A key input or

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[1] Lawrence and Wang (1997) for hogs use an eight week rolling average on soybean meal and corn. The inputs are 350 pounds of feed (80% corn and 20% soybean meal) per cwt. of hog marketed plus other costs of \$35/ton of feed, \$14/cwt of animal sold and an additional \$5/cwt as part of the "plus". This forms the function for the minimum price (i.e. $K^I_{L,t}$). The maximum price (i.e. C) is adjusted upward by setting C=\$5/cwt.

assumption to value these contracts is the stochastic process used for the price distribution. This topic is addressed next.

Stochastic Processes

Option models are used to value puts and calls. The window contract is composed of simple options on the market output price. The Black (1976) model used to value these window contracts (Unterschultz et al. 1997) requires that the underlying asset price follow a log normal stochastic process (i.e. the short term asset returns are a random walk: $dS/S = \alpha dt + \sigma dz$ where S is the asset price, α is the non stochastic drift rate (trend), σ is the non stochastic instantaneous variance and dz is brownian motion).

The cost-plus contract is composed of options on the spread between input prices and output prices. Since spread values can become negative and two or more stochastic variables are in the option, the Black model is not suitable for valuing these contracts. Presumably these spread variables are related both in theory and in practice. If these variables are co-integrated then this should imply that there are bounds on the value of the spread options even if the individual prices appear to be non-stationary. Several valuation issues for these long-term options arise. These are:

- What is the most appropriate stochastic price process to use (i.e. are the price processes stationary or non-stationary)?
- What type of models are required given the stochastic price process?
- What input variables should be used for long term contracts since futures prices, the preferred input price, in general do not trade beyond two years into the future?
- How can the model be tested or evaluated to determine if the calculated prices are reasonable when markets for these contracts do not yet exist?

The finance literature is addressing many of these issues for non-agricultural commodities (Schwartz, 1997; Gibson and Schwartz 1990 1991; Brennan 1991; Shimko 1994) and we address the first three issues in this paper. Irwin, Zulauf and Jackson (1996), using seventeen years of data, conclude statistically that prices for corn, soybeans, wheat, live hogs and live cattle do not have mean-reversion. This suggests that a log normal distribution may be suitable even for valuing these long term contracts. However Pindyck and Dixit (1994, p.78) assert that using only 30 or so years of data, it is difficult to distinguish between a random walk verses a mean reverting process. Thus they recommend that the individual use theoretical considerations (i.e. equilibrium mechanisms in the sector) to determine whether mean-reverting price processes are appropriate. In particular commodity prices should revert to long run marginal costs. Schwartz (1997) examines several different reverting models for non-agricultural commodities and concludes that the reversion parameters are significant.

Two different price processes are compared in this paper. The first process assumes that all the prices follow a log-normal price process. That is:

$$dS_i = \alpha_i S_i dt + \sigma_i S_i dz_i \quad i = l \ldots j \qquad (3)$$

where S is the spot price for commodity i, α is the drift rate (expected rate of return in a risky world), dt is the time increment, σ is the standard deviation of the process (volatility), dz_i is standard normal brownian motion and ρ_{ij} is the correlation between dz_I and dz_j. Volatilities and correlations are estimated using simple daily returns.

The second process assumes a mean reverting process following model in Schwartz (1997). This process is:

$$dS_i = k(\mu_i - \ln(S_i))S_i dt + \sigma_i S_i dz_i \quad i = \\ \textit{or} \text{ equivalently by setting } X_i = \ln(S_i) \\ dX_i = k_i(\alpha_i - X_i)dt + \sigma_i dz_i \tag{4}$$

where k measures the degree of reversion to long run mean log price α_i. This process has a simple discrete version for parameter estimation. Parameters are derived by estimating the model:

$$X_{i,t} = a_i + b_i X_{i,t-1} + e_i \quad \text{where } \mathrm{Var}(e_i) = \sigma_i^2 \tag{5}$$

The Schwartz model and the lognormal model are simplified here by assuming the Capital Asset Pricing Model provides an adequate measure of the market price for risk. Further details are in Schwartz (1997). The data used to estimate the parameters for the different price processes are discussed next.

Data Description and Analysis

Futures price series for live cattle (Chicago Mercantile Exchange-CME), feeder cattle (CME), lean hogs (CME) corn (Chicago Board of Trade-CBOT) and soy bean meal (CBOT) are evaluated. The historical lean hog contract was adjusted to a lean basis. Bridge-CRB provided the futures data. The nearby futures contracts were spliced together to provide a proxy measure for the prevailing daily or monthly cash prices for each of these commodities. Although more data are available, the data analyzed covered the period January 1987 to December 1997 (i.e. 11 years of data). The US CPI index was used to deflate the price series when inflation adjusted analysis was performed. The S&P 500 index was used for estimating CAPM.

Seemingly unrelated regressions (SUR) estimation was used on equation (5) for all five commodities to estimate volatilities, correlations, log of the long run mean and reversion parameters. The results for the correlations and volatilities are reported in Table 1. Estimates using price data adjusted for inflation were also included to evaluate differences in parameter estimates. These are also found in Table 1. The correlation and volatility estimates are similar to the simple estimates derived using daily data. The important correlations to note are the small relationship between lean hogs and corn/soybean meal. Feeder cattle are more highly correlated to corn and live cattle. While not formally tested, this suggests a stronger equilibrium relationship in the cattle complex than in the pork complex.

The reversion parameters, reported in Table 2, are the annual rate of reversion (k_i) to the long run log of the mean (α_i). Lean hogs exhibit the strongest reversion parameter, 1.99, when estimated using data not adjusted for inflation. The log of the long run mean for lean hogs is 4.17 or approximately \$64.5/cwt[2]. Schwartz (1997) has further details on how these parameter estimates are related. Statistical significance of the results was not tested since the primary objective was to provide parameter estimates for mean reverting price distributions. To evaluate different model assumptions, both inflation adjusted and nominal parameter estimates are used to simulate window and spread options. The beta CAPM estimates (Table 2) indicate that these commodities exhibit little systematic risk. These parameter estimates are used to evaluate pricing in window and spread contracts discussed next.

Monte Carlo Model Valuation

Monte Carlo simulation techniques are used to value window and spread options on lean hogs and spread options on live cattle (i.e. finished beef animals). Details on the risk neutral stochastic price processes based on equations (3) and (4) used in the Monte Carlo are found in Hull (1993). Essentially, Monte Carlo techniques are used to simulate the potential price paths through time in a risk neutral world. The option value is calculated at the end of the price path and discounted at the risk free rate. This process is repeated many thousands of times (i.e. usually 10 to 20 thousand) to arrive at an initial option value. The market price of risk is required for these simulations and the risk free interest rate is assumed to be 7%.

Ten year contracts that covered production at 1 year, 1.5 years, 2 years, 2.5 years to 10 years were assumed. Weekly prices were simulated to represent the price paths for up to ten years into the future. That is, contract options values were calculated with one year to maturity, then a new set of price paths was generated for 1.5 years to calculate the option values at 1.5 years and so on.

Prior to valuing window contracts and spread contracts, the difference between the random walk price process (equation 3) and the mean reverting process (equation 4) is illustrated. Using the parameter estimates from Tables 1 and 2 for lean hogs, (not adjusted for inflation), a single price process generating a random walk and a mean reverting process are given in Figure 1 (10 years) and Figure 2 (40 years). The same random process, a set of random price shocks, is used to simulate both series shown in Figure 1. Initially the random walk and the reverting process are similar, however the mean reverting process eventually returns to the mean. The random walk continues to wander. Both processes exhibit wide variations in price but the greatest variation is observed in the random walk. Figure 2 illustrates a different set of random events over 40 years. The same series of random shocks (i.e. news events, demand shocks, weather etc) generate the price movements for both price processes. This clearly illustrates how similar a random walk and a strong mean reverting process appear over shorter time intervals of ten to twenty years. This also illustrates the drawback to ad hoc price adjustments to window contracts as discussed by Lawrence and Wang (1997). Extending the term of the contract may

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[2] The instantaneous rate of reversion is approximately \$9.55/cwt (annually) if the spot price is \$60/cwt, the mean is \$65/cwt and the reversion parameter is 1.99.

not do anything to improve the cash position of one party relative to the counter party, especially if the price series exhibits the traits of a random walk.

Long term window contracts for lean hogs (i.e. dressed weight) are simulated using the parameter estimates (adjusted for inflation). The reverting process assumes a mean of $75/cwt. The call and put strike prices are 80 and 70 respectively. The put and call premium could be equalized for each time to maturity by adjusting the strike prices for each specific maturity but this is not attempted here. Figures 3, 4,and 5 illustrate options premiums ranging from one to 10 years in maturity. The option values based on the random walk (non-reverting process) illustrate how much more valuable the implicit price floors and price ceilings are in window contracts. Figure 3 shows that choosing a window where the floor price is equally distant from the current price as the ceiling price does not result in a completely "fair" window value if prices follow a random walk. A "fair" window would have the put premium equal the call premium at each maturity date such that there is no net benefit to either the producer or the processor when the contract is signed. The reverting process shows that the call option and the put option have almost equal value through out most of the time period. The most obvious difference is the much lower option values for the reverting process. Current prices $10/cwt above or below the long run mean (Figures 4 and 5) have little impact after year 2 on the option values generated using a mean reverting process. Different windows would be required for different times to maturity to provide a fair contract under the assumptions used to generate Figure 5. The impact of spot prices outside the range of the floor and ceiling price are quite large if the option premiums are generated using a random walk. Sensitivity analysis (not shown) illustrates that even relatively lower levels of reversion cause major reductions in the value of long-term options.

These window contract results highlight several key points. Knowledge about the underlying price process is essential before entering into long term contracts. The price risks are substantial if prices during the period of the window contract exhibit traits similar to a random walk or if the price window is not correctly chosen. This in part explains the substantial benefits Lawrence and Wang (1997) show accruing to one party under their historical simulation for hog window contracts. Different strike prices may be required for different times to maturity if the value of the floor price (put option) is to equal the value of the ceiling price (call option). Window contracts can be fairly priced at the beginning, however under the random walk hypothesis, it is highly likely that one party will end up substantially ahead. With a mean reverting process, if the mean is correctly identified and the floor and ceiling prices correctly placed then the window contract option values are smaller and current deviations of the spot price from the long run mean have little impact on option values expiring after two years. The key point here is to correctly identify the mean and then determine the price window under the reverting process hypothesis.

Next lean hog spread contracts were simulated using the parameter estimates for corn, soybean meal and lean hogs reported in Tables 1 and 2 (not adjusted for inflation). Production relationships between corn, soybean meal and hogs similar to those presented by Lawrence and Wang (1997) are used to estimate the spread floor. These are:

- 0.78 converts live weight to carcass
- 400 total pounds of feed per cwt. live weight
- 0.8 portion of feed that is corn
- 0.2 portion of soybean meal in feed
- $35/ton of feed and $14/cwt of animal are other costs
- $8.0/cwt live weight cost plus in the contract for the spread ceiling
- Spot price equal to the mean at the time 0

Spread contracts for lean hogs are illustrated in Figure 6. Under a random walk two facts are immediately evident. The cost plus factor of $8 is too low given the parameters and production assumptions. The option premiums are still substantial when compared to the option premiums simulated using the mean reverting process. Option premiums when the price processes follow a reverting process and the "true" parameters are known are much smaller.

A similar spread option for live cattle (finished cattle) is simulated based on live cattle, feeder cattle and corn prices using Tables 1 and 2 values (not adjusted for inflation). As demonstrated below, the higher correlations between the cattle complex versus the lean hog spread have a major impact on the option values. Again a very simple production function is used for illustrative purposes. This function is:

- 7=feed conversion rate i.e. 7 lbs. of feed for 1 lb. of gain
- 1.09 =conversion on corn price to get cost of ration consumed
- 800=feeder cattle incoming weight (lbs.)
- 1200=finished live weight (lbs.)
- 3=rate of daily gain (i.e. 3lb/day)
- 0.2=yardage charge per day per animal
- $28= other fixed cost such as buying=$5, trucking=$3, deathloss=$10, processing=$3 veterinary=$7
- $20=cost plus amount per animal
- Spot price equal to the mean at the time 0

The live cattle spread contract is illustrated in Figure 7 and assumes the spot price is at the mean. Despite the smaller volatilities associated with cattle prices versus hog prices, the reverting price process has higher spread option values for cattle. This result appears to be driven by the larger absolute values on the correlations between live cattle, feeder cattle and corn returns. Figure 8 further highlights this point for the call values on the spread. The model where all price reversions and correlations are zero is similar to the premiums when the reversion is non-zero but correlations are also non-zero. Small spread option values only occur when the correlations are set to zero. The larger non-zero correlations in the cattle spread result in relatively higher spread option premiums and counter part of the impact of the reversion parameter. Further simulations, not shown here, indicate the key correlation driving this result is the negative correlation between corn and feeder cattle returns. That is, the reversion parameter is less important for spread options where the prices appear to be co-integrated.

These spread contract simulations highlight several key points about cost plus contracts. The choice of the production relationship and the size of the cost plus are critical to the success of these contracts. The correlations can have a very important impact on the option value and hide the impact of any reversion component on the spread option value. The implied option values in cost plus contracts can be substantial. Equalizing the value of the put spread and the call spread may require that the cost plus component be adjusted for different times to maturity.

Conclusions

Commodity pricing contracts are being used for managing risk in long term producer-processor contracting relationships. These contracts include long-term window contracts and cost plus contracts. These contracts can be decomposed into portfolios of puts and calls. In theory these puts and calls can be valued. However, several valuation constraints exist with long-term contracts that are lessor issues with shorter-term contracts. A key input or assumption to value these contracts is the stochastic process used for the price distribution. Information on whether the series is stationary or non-stationary is a critical valuation issue.

Work remains to further evaluate the parameters of the stochastic process and consider alternative stochastic processes that provide more accurate representation of the underlying price series. Future work could evaluate the impact of different mean reverting processes, stochastic interest rates or stochastic volatility on long term contracts in agricultural commodities.

Table 1: Systems Estimates of Standard Deviations and Correlations Using Autoregressive Models

Commodity	Soybean Meal	Corn	Lean Hogs	Feeder Cattle	Live Cattle
	Price Data Not Adjusted For Inflation				
Soybean Meal	1.00				
Corn	0.54	1.00			
Lean Hogs	0.16	0.16	1.00		
Feeder Cattle	-0.27	-0.44	-0.01	1.00	
Live Cattle	-0.22	-0.19	-0.20	0.51	1.00
Std Dev.	0.18	0.21	0.23	0.10	0.13
	Price Data Adjusted For Inflation				
Soybean Meal	1.00				
Corn	0.55	1.00			
Lean Hogs	0.17	0.17	1.00		
Feeder Cattle	-0.21	-0.38	0.03	1.00	
Live Cattle	-0.18	-0.16	-0.18	0.52	1.00
Std. Dev.	0.18	0.21	0.23	0.10	0.13

Table 2: Reversion Parameter and Capital Asset Pricing Model Beta Estimates

	Soybean Meal	*Corn*	*Lean Hogs*	*FeederCattle*	*LiveCattle*
	Price Data Not Adjusted For Inflation				
Log of Mean[1]	5.33	3.28	4.17	4.37	4.27
Reverting Parameter[2]	0.78	0.96	1.99	0.79	1.34
	Price Data Adjusted For Inflation				
Log of Mean[1]	5.45	3.40	4.30	4.44	4.29
Reverting Parameter[2]	0.64	0.88	1.46	0.23	0.18
CAPM Beta[3]	-0.24	0.12	0.041	0.20	0.14

1. This is the α_i from the reverting stochastic process (equation 4).
2. This is the k_I from the reverting stochastic process and measures the degree of reversion to the long run log mean price α_i.
3. CAPM estimated using price data not adjusted for inflation.

Figure 1

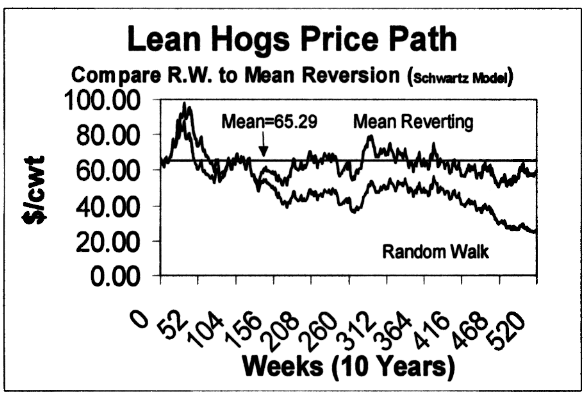


Figure 2

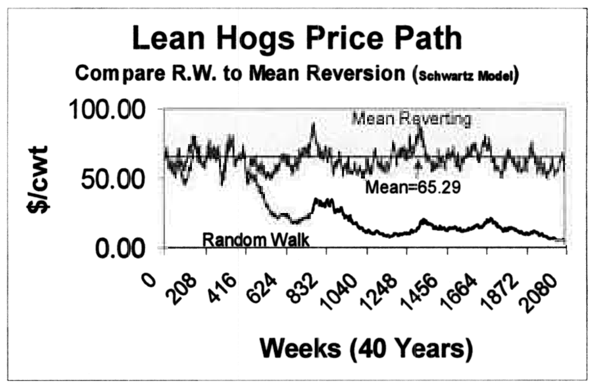


Figure 3

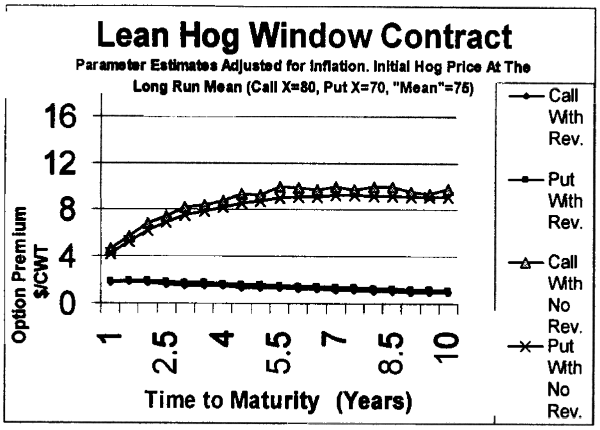


Figure 4

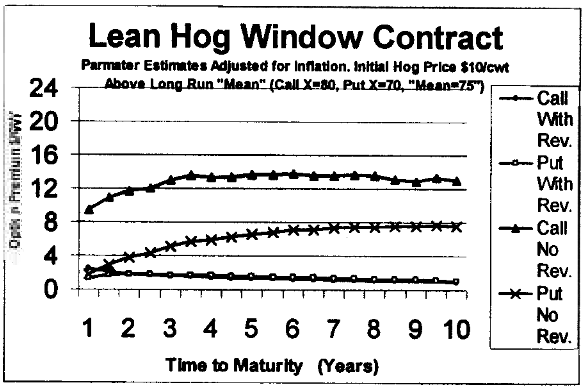


Figure 5

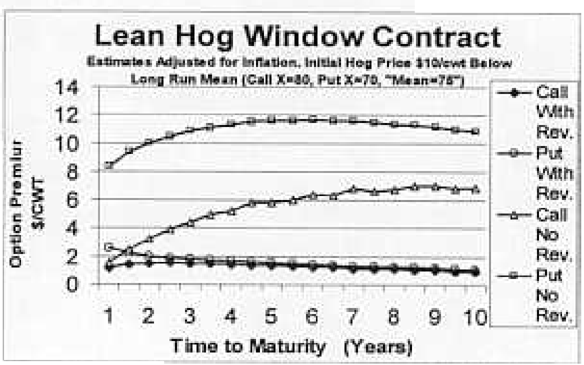


Figure 6

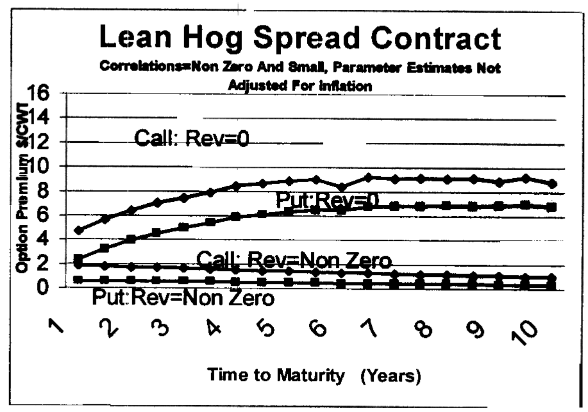


Figure 7

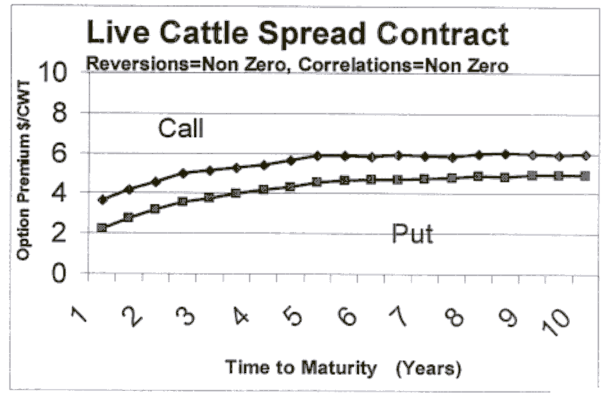
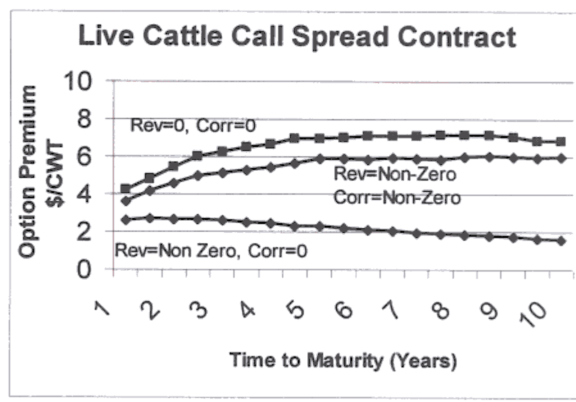


Figure 8



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