HOG OPTIONS: CONTRACT REDESIGN AND MARKET EFFICIENCY

by

Hernán A. Urcola and Scott H. Irwin*

This version: July, 2009

*Hernán A. Urcola (hernanurcola@gmail.com) is a Researcher in the Agricultural Economics & Rural Sociology Area at the National Institute of Agricultural Technology (INTA) at Balcarce, Argentina and holds a doctorate from the University of Illinois at Urbana-Champaign. Scott H. Irwin is the Laurence J. Norton Chair of Agricultural Marketing in the Department of Agricultural and Consumer Economics at the University of Illinois at Urbana-Champaign.

HOG OPTIONS: CONTRACT REDESIGN AND MARKET EFFICIENCY

Abstract

The objective of this article is to test the efficiency of the hog options market and to assess the impact of the 1996 contract redesign on efficiency. We find that expected returns are small and do not appear to yield economically significant profits. The comparison of live and lean hog period option returns indicates that some moneyness categories yield excess risk-adjusted profits during the live hog period, but not during the lean hog period. Our findings indicate that the hog options market is efficient and that the contract redesign improved the pricing ability of this market. Mispricing claims may be caused by biases in the agents' perceptions of futures price distributions.

Key words: hog options, mispricing perceptions, contract redesign, trading returns.

JEL Classifications: C15, G12, G14, Q13

HOG OPTIONS: CONTRACT REDESIGN AND MARKET EFFICIENCY

For more than 20 years the hog option contract has served as an important risk management tool in the pork industry and, as a consequence, its trading volume has increased eighteen times between 1985 and 2008. Traditionally, the hog futures contract was settled under a physical delivery system, but, following structural changes in the hog industry, the Chicago Mercantile Exchange (CME) redesigned the contract in 1996. The contract redesign aimed to improve the price discovery and hedging functions of hog futures and options. While the new contract has grown substantially in trading volume, market participants have expressed concern that option premiums are too high. Lawrence and Grimes (2007) review changes in production and marketing practices and survey the reasons why producers do not use options when marketing hogs. Most small and medium size producers cite high option premiums as a reason not to use the hog option market. Similar concerns about the cost of agricultural options have been noted previously (Irwin, 1990; Williams, 2003).

The existing literature about hog options market efficiency is composed of only three studies, each of them indicating some degree of option mispricing. Szakmary et al. (2003) and Egelkraut and Garcia (2006) used implied volatility (IV) to test options market efficiency and McKenzie et al. (2007) analyze simulated option returns on the days surrounding the release of the United States Department of Agriculture (USDA) Hogs and Pigs Reports (HPR). Szakmary et al. (2003) and Egelkraut and Garcia (2006) found implied volatility to be a biased forecast of subsequent realized volatility, thus indicating option mispricing. However, testing options market efficiency with IV has two important limitations. First, IV identifies biases in the volatility forecast, but this constitutes an indirect test of efficiency because even with biases in the volatility forecast it still might not be possible to obtain systematic trading profits and the market could still be efficient. Therefore, IV tests do not allow one to draw a definitive conclusion about options market efficiency. Second, it is not possible to quantify the effect of transaction costs on trading returns using IV tests.

McKenzie et al. (2007) examine simulated returns to long straddles established and exited around the release dates of the HPR and show that returns are significant for low levels of transaction costs. It is worth noting that McKenzie et al. (2007) analyze the hog options market only during a few trading days a year, because the HPR is released quarterly for the most part of their sample period.

Because options are normally used as price insurance, market efficiency is critical for producers and processors. Market participant may lose substantial amounts of money if they use overpriced options. Risk-averse agents may be willing to pay for insurance, but if option premiums are too high, the benefits of price insurance might be outweighed by the cost of purchasing the insurance. Also, option mispricing is relevant to academic researchers because of competing models of asset pricing. For some time, the main model used to describe the behavior of market prices has been the Efficient Market Hypothesis (EMH). In an efficient market, prices always "fully reflect" available information, thus it is not possible to obtain systematic trading profits. However, the empirical evidence about the EMH is mixed and several anomalies have been documented for options markets (e.g., Coval and Shumway, 2001; Bondarenko, 2003; Bollen and Whaley, 2004).

The above discussion reveals that, despite its importance, evidence regarding the efficiency of the hog options market is scarce and inconclusive. Additionally, no study has evaluated the impact of contract redesign on the efficiency of the hog options market. The objective of this article is to test the efficiency of the hog options market by computing simulated trading returns and to assess the impact of the contract redesign on trading returns.

To implement the analysis, returns from different simulated trading strategies are computed and used to test the sufficient condition for market efficiency — that expected returns equal zero. Trading strategies for calls, puts, straddles, and two types of strangles are simulated using decision rules that increase the likelihood of obtaining profitable trades. These strategies allow assessing the pricing ability of the market for options with different degrees of moneyness and do not depend on a precise forecast about the movement of the futures price. Also, simulated trading strategies are model-free and allow the effect of transaction costs on trading returns to be quantified. Furthermore, returns from the live and the lean hog periods are compared to assess the impact of contract redesign on market efficiency.

Using a dataset that begins at the resumption of the hog options trading, we find that expected returns are small and do not appear to yield economically significant profits. The assessment of the contract redesign indicates that some moneyness categories yield excess risk-adjusted profits during the live hog period, but not during the lean hog period. Our findings indicate that the hog option market is efficient and suggest that the contract redesign improved the efficiency of the hog options markets.

The article is organized as follows. The next two sections review the hog futures contract and the theory of efficient markets. The third section outlines the data used. The fourth and fifth sections describe the simulated trading strategies and present the empirical returns for the entire sample period and separately for the live and the lean hog contract periods. The conclusion section closes the article.

The Hog Futures Contracts

Most agricultural futures contracts are settled using the physical delivery method. Under this system, a seller (buyer) that maintains an open position until the contract expiration must make (take) delivery at a number of specified locations to liquidate the position. The settlement mechanism should guarantee the convergence between the cash and future price at the contract expiration date, otherwise arbitrage opportunities would arise. The physical delivery method can entail relatively high costs given that the commodity must be transported and the delivery facilities must be inspected periodically. Additionally, the list of delivery locations must be revised periodically to accurately represent usual business practices (Lien and Tse, 2003).

Alternatively, futures contracts can be settled against a cash index that determines cash payment transfers to liquidate the positions standing at expiration. The effectiveness of this type of contracts depends critically on the construction of a reasonable index (Lien and Tse, 2003). A critical feature of the cash index is the number of delivery locations it includes. For instance a broad-based index including prices from several reporting stations reduces the likelihood of market manipulation. However, a narrow-based index improves hedging effectiveness (Chan and Lien, 2001). If the contract specification does not represent common business practices the futures price would not represent the expected cash price. Such distortions would introduce option mispricing, because option premiums are function of the futures price.

During the 1990's, the hog industry experienced deep changes in size, degree of horizontal and vertical coordination and concentration; as a consequence, some authors assessed the benefits of a cash-settled hog futures contracts. These studies concluded that a cash-settled hog futures would provide better convergence between cash and futures, have lower basis variability and improve hedging effectiveness with respect to the existing physically settled contract (Kimle and Hayenga, 2004; Ditsch and Leuthold, 1996).

With the goal of reflecting changes in the hog industry, the CME redesigned its hog futures and options contract beginning with the February 1997 contract, which began trading in November 1995. The new lean hog contract settles against a two-day weighted average index of the United States Department of Agriculture (USDA) cash prices for producer-sold swine or pork market transactions. Because terminal prices are not included, the index reflects prices paid by slaughterhouses to hog producers, thus better representing a market with increasing levels of horizontal and vertical integration.

The main contract specifications for the live and lean hog contracts are presented in Table 1. The main changes include the underlying commodity, the settlement method, the introduction of the May futures contract in 2001 and the change in the option expiration date. The May futures and options initial trading volume is relatively low compared to other contracts. To assess possible biases in returns introduced by this contract, May option were excluded from the returns computations. However, the same qualitative results were obtained, thus May options were maintained in the analysis. Also, during the live hog period, options expired two to three weeks before the futures last trading day. However, during the lean hog period, options expire on the futures last trading day. This modification should not change the fact that, whatever the expiration date, expected option returns should equal zero, under market efficiency.

[PLACE TABLE 1 ABOUT HERE]

Market Efficiency Theory

The efficient market hypothesis states that an efficient market is one in which market prices reflect all information available about the asset. While individual market participants might incorrectly assess expected prices, in aggregate the market makes no systematic mistake about true asset prices. Since prices reflect the true value of the assets, it is not possible to consistently make profits by trading those assets. In other words, the EMH says that no one can "beat the market." Fama (1970) formally stated the EMH as,

$$E[r_{j,T} \mid \Phi_t] = 0. \quad (1)$$

where $r_{j,T}$ represents the return to trading the jth option realized at time T, Φ_t is the information set available at time t, and E[·] is the expectation operator.

Jensen (1978) defines economic profits as the risk-adjusted returns net of all costs. Therefore, this definition implies that market efficiency has to be tested taking into account not only transaction costs but also the risks inherent in the trading strategies employed. The author also identifies three versions of the EMH according to the definition of the information set Φ_t. These groups are *weak form*, *semi-strong form* and *strong form* when Φ_t is formed by historical price up to time t, only; all publicly available information; and all information known to anyone at time t, respectively. This last form includes both public and private information.

Over the years, mixed evidence has been reported about the validity of the EMH and several authors document anomalies that stand against the EMH (e.g., Chiras and Manaster, 1978; Galai, 1978). However, Fama (1998) reviews a large body of literature concluding that the EMH is a valid representation of market behavior and that anomalies such as over-, under-reaction, trends and mean reversion are chance results that are in most cases due to methodology. Nevertheless, the EMH does not appear to predict well the expected returns of put and call options. Several authors analyze trading strategies in the S&P500 futures option markets and find evidence against efficiency (Coval and Shumway, 2001; Bondarenko, 2003; Bollen and Whaley, 2004). These studies conclude that simple strategies that sell options yield significant excess returns.

Similarly, several studies have found evidence of mispricing for agricultural options. In particular, implied volatility (IV) appears to be a biased forecast of subsequent realized volatility for corn, soybeans and wheat futures (Myers et al., 1996; Szakmary et al., 2003; Egelkraut and Garcia, 2006). However, in contrast with these studies, Simon (2001) uses a combination of IV methods and of simulated trading strategies and finds that corn, soybean and wheat options are not mispriced. A different set of studies find excess returns and biased volatility forecasts when analyzing cattle options (e.g., Hauser and Liu, 1992; Manfredo et al., 2001; Manfredo and Sanders, 2004). Recently, studies by Szakmary et al. (2003) and Egelkraut and Garcia (2006) raise questions about the pricing ability of the hog options market as these studies find implied volatility to be a biased forecast of subsequent realized volatility. Such biases indicate that options are either over- or under-estimating the volatility of the futures price. Consequently, abnormal returns potentially can be made by trading these options.

Szakmary et al. (2003) and Egelkraut and Garcia (2006) employ Black's (1976) model to derive IV from option premiums and forecast the futures volatility. Szakmary et al. (2003) study IV forecasts in 35 different options markets, including agricultural markets. This study uses IV to forecast the subsequent market volatility expected to prevail during the following calendar month. In contrast, Egelkraut and Garcia (2006) use IV to forecast the realized volatility of corn, soybeans, soybean meal, wheat and hogs futures during an intermediate future time interval. The authors define this forecast as implied forward volatility (IFV).

Analyzing the relationship between hog options IV and RV, Szakmary et al. (2003) find that IV is relatively high, RV tends to be lower, and vice versa which indicates that options are mispriced. The authors also test whether option premiums efficiently incorporate all the information regarding the futures volatility. If option prices reflect all available information, the regression coefficient associated with historical volatility (HV) should be not statistically different from zero since HV should have no explanatory power beyond that already incorporated in IV. Szakmary et al. (2003) find a significant coefficient for HV suggesting that hog option premiums do not reflect all the available information about expected future price volatility. Similar to Szakmary et al. (2003), Egelkraut and Garcia (2006) also find biases of the IFV when predicting future realized volatility. However, these authors find that HV does not improve the forecast provided by IV.

McKenzie et al. (2007) employ the trading strategy approach to test the efficiency of the hog options market by computing the profitability of long straddles established around the release dates of the HPR. Long straddles are profitable whenever the underlying futures volatility increases or when there are large price movements in either direction. Analyzing data from 1985 through 2005, McKenzie et al. (2007) show that if transaction costs are low enough a floor trader could obtain systematic profits. However, profits are heavily dependent on the level of transaction costs, and the hog options market appears efficient for off-floor traders. It is worth noting that McKenzie et al. (2007) analyzed options market efficiency only in the days surrounding the release of the HPR. Thus, the authors analyze the hog options market efficiency during specific trading days only.

The discussion above indicates that the EMH may fail to describe the behavior of option markets. However, the existing evidence regarding hog options market is based on only three studies. Two of these studies use almost identical research methods and the third analyzes the market only during specific days of the year. The next section presents the data used in the analysis.

Data

Daily settlement prices for hog futures and options are used in this study. Option and futures data come from the CME and from Barchart. The short-run interest rate is proxied by the 3-month Treasury Bill rate and is from the Federal Reserve Bank. All data cover the period 2/1/1985 to 12/31/2005. Hog options traded at the CME are American-type options that can be exercised at any time prior to expiration, as opposite to European-type options which can only be exercised at expiration. The analysis conducted in this article does not use any option pricing model and should not be affected by the option's type.

Daily settlement prices of options are used in the analysis. At the CME the underlying futures and the options are traded side-by-side, which implies that the options and futures prices should be highly synchronized, alleviating the problem of nonsynchronous/stale prices. Another advantage of using settlement prices is that these prices are first scrutinized by the settlement committee and then by exchange staff members, because they are use by the Clearing Corporation to compute the margin requirements.[1] Because of this double inspection, settlement prices are less likely to constitute stale prices, to have clerical measurement errors or to violate non-arbitrage restrictions. Therefore, settlement prices provide a good approximation to prices at which options could have been actually traded.

Also, the dataset is filtered to exclude uninformative observations according to volume traded, strike price convexity and minimum option premium. Options with zero volume are reported by the exchange, but do not constitute actual trades; thus they are not used in the analysis. Also, options with premiums inconsistent with monotonic strike prices are removed from the dataset. Finally, options whose prices are less than three times the minimum tick size are also excluded. These filters are intended to exclude illiquid options whose prices contain little market information and that can bias the computations toward extreme returns. Similar filters have been applied in previous option studies (Coval and Shumway, 2001; Bondarenko, 2003; Egelkraut and Garcia, 2006).

Call and Put Options Returns

Call and put returns are computed from a trading strategy that buys options with 30 calendar days to expiration and holds them until expiration.[2] Then, a new set of identical options is bought and held until they expire, and so on. Returns from this trading strategy are relevant for any risk-averse trader, producer or processor that uses hog options in his/her business. This trading scheme yields non-overlapping return observations and minimizes the effects of transaction costs and/or bid-ask spreads because it involves trading each option only once.

Through the analysis, options returns are estimated assuming three levels of transaction costs: zero transaction costs, transaction costs faced by a floor trader and transaction costs faced by an off-floor trader. Options markets transaction costs can be broadly divided into two categories, brokerage commissions and the bid-ask spread. A floor trader would only face the bid-ask spread portion of the costs, as this trader would not need to pay brokerage commissions. In contrasts, an off-floor trader transaction costs are composed of bid-ask spread plus brokerage commissions.

To date, an estimate of bid-ask spreads for hog options markets is not available. Following previous option studies the trading simulations assume 1/2 tick is paid as a round trip cost for trading each option because in the simulated strategies options are traded only once (Simon, 2001; Szakmary et al., 2003). Also, several studies have found hog futures round trip costs of about 1 tick (e.g., Locke and Venkatesh, 1997; Ferguson and Mann, 2001; Frank and Garcia, 2007). Therefore, it is assumed that 1/2 tick is paid to offset the futures contract once the option has been exercised. Brokers' commissions are surveyed from several brokerage services and a \$30/contract round trip fee plus a \$2/contract to exercise the option at expiration represents a typical trading commission charged by brokerage services through the sample period. Therefore, per contract transaction costs for floor and off-floor traders are \$10 and \$42, respectively. Simon (2001) uses similar commission costs.

Since long option positions are established, put (call) options earn money when the futures price decrease (increase). When these long positions make money the complementary short position loses money. Consequently, determining that long positions earn positive returns indicates that short positions earn negative returns. The percentage returns to a put, $r_{p,K}$, and to a call, $r_{c,K}$, are computed respectively as,

$$r_{c,K} = (\max(F_T - K, 0)/c_{K,t} - 1) * 100 \quad (2)$$

$$r_{p,K} = (\max(K - F_T, 0)/p_{K,t} - 1) * 100 \quad (3)$$

where $p_{K,t}$ and $c_{K,t}$ are respectively the price of the put and of the call with strike price K at time t and F_T is the price of the underlying futures at the expiration of the option. In order to better assess the economic significance of option returns, mean percentage returns are also expressed in dollars per contract basis. Dollar term profits can be easily compared with alternative investments. From equations (2) and (3) percentage returns for calls and puts can be expressed in dollars per contract as, $r_{p,K}/100 * c_{K,t} * 400$ and $r_{c,K}/100 * p_{K,t} * 400$, respectively.

Options market efficiency tests are implemented by testing whether expected observed returns equal zero. That expected options returns are not statistically different from zero would imply that the equality in (1) holds and that the options market is efficient (Fama, 1970). Returns are presented and analyzed grouped into five moneyness categories, which are defined by the ratio $k = K/F_t = 0.94, 0.97, 1.00, 1.03, 1.06$. The grouping into moneyness allows assessing whether the computed statistics vary across moneyness (e.g., Coval and Shumway, 2001; Bollen and Whaley, 2004). A sixth return category is created by pooling returns across moneyness categories. The pooled returns describe gain/loses of an investor trading all the considered options in a single portfolio.

In order to test whether expected options returns are statistically different from zero, bootstrapped confidence intervals are constructed. Bootstrapping uses the sample data to obtain a description of the sampling properties of empirical estimators when asymmetries in the return distribution might limit the reliability of the usual t-statistic. Bootstrapped confidence intervals are not affected by asymmetries in the distribution of returns. Given a sample of reasonable size and a consistent estimator the asymptotic distribution of the estimator can be approximated by drawing observations from the data a given number of times. Then, from each of the bootstrapped samples the estimator is computed (Greene, 1997). Since the mean is a consistent estimator, observations are drawn, with replacement, from each of the return vectors for calls and puts in each moneyness category and for straddles and strangles. Then, the mean return is computed from the bootstrapped vectors. This process is repeated 2000 times. Next, the 5% and 95% percentiles for the distribution of the mean return are computed. These percentiles are computed for puts and calls in each moneyness category and for straddles and strangles and they indicate the range within which the true mean return lie, with 95% confidence.

Returns to buying and hold call and put options during the period 1985 − 2005 are presented in Table 2. Returns, presented by moneyness, are from the buyers perspective, thus, if a buyer and a seller face similar transaction costs, a positive return indicates a profit to the buyer and a loss to the seller, and vice versa for a negative return. Figure 1 plots the nearby hog futures price throughout the sample period. No strong trends were present during the sample period, the linear trend has a slope of \$−0.0008/day. However, a rapid expansion of hog production facilities caused major drops in futures prices in December 1998 and September 2002.

[PLACE FIGURE 1 ABOUT HERE]

In general, hog option returns are highly variable and characterized by several extreme returns along the sample period. For instance, ATM puts expires worthless 59% of the time but provide returns as large as 912.7% and 1,504.4% (figure 2). Therefore, the holder of one these puts loses the premium most of the time, but obtains large positive returns on occasions. The distributions of hog option returns vary across moneyness. The largest standard deviations are for out-of-the-money options. Hog option standard deviations range from 682.2% to 90.3%. (Table 2). The skewness of the return distribution increases when the option is more OTM.

[PLACE FIGURE 2 ABOUT HERE]

Zero transaction costs option returns appear profitable for buyers, on average, across moneyness categories. For instance, an investor buying and holding a hog call with $k = 0.94$ for 30 days would have gained on average 13.8¢ on the dollar (Table 2, Panel A). Across moneyness categories, hog option returns are positive in 9 out 10 cases. Considering the positive cases, monthly profits for the holder of the options range from 3.6% to 20.8% for calls and from 4.2% to 42.1% for puts. Hog option pooled returns are positive for calls and puts. Per contract returns for hog options are, in general, small in absolute value ranging from $-249 for puts with $k = 1.06$ to $149 for calls with $k = 0.94$ (Table 2, Panel A). [3]

[PLACE TABLE 2 ABOUT HERE]

Although hog options appear profitable for buyers, returns are highly variable indicating that buyers cannot expect to obtain consistent profits given that all 95% confidence intervals for the mean include the zero return. As a consequence, none of the observed expected returns are statistically significant (Table 2).

Trading returns discussed thus far inform about the returns calculated from settlement option prices, but do not include transaction costs. Floor trader returns exhibit a similar pattern to zero transaction cost returns but are smaller because of the bid/ask spreads paid (Table 2, Panel B). None of the moneyness categories for calls or puts produces substantial gains for floor traders, with the exception of calls with moneyness $k = 0.94$, which yield an average gain of $139/contract. Furthermore, none of the floor trader returns —percentage or per contract returns— are statistically significant.

When off-floor traders' transaction costs are considered, expected returns for five moneyness categories and the pooled return for puts are negative, although small in absolute value (Table 2, Panel C). The smallest and the largest percentage returns are, respectively, -20.7% and 11.9%. When brokers' commissions are considered, per contract returns are also smaller, ranging from $-291 to $107. Off-floor trader returns are, in general, small in absolute value indicating that returns to either buyers or sellers of these options are not economically large. Also, none of the returns presented is statistically different from zero, as all bootstrapped confidence intervals contain the zero return. These results indicate that when, analyzing the whole sample period, hog options appear efficiently priced and that it is unlikely that either floor or off-floor traders can obtain systematic profits by trading these options.

The lean hog futures suffered a major drop in December 16, 1998 when reached its minimum for the sample period of $27.95/cwt. This low price might potentially drive option returns, and bias conclusions of this study. Therefore, options returns were re-computed excluding from the analysis the observations corresponding to the Dec–98 option contract. No significant difference were found in historical returns when results were re-calculated without the Dec–98 contract. The next section explores possible differences in option returns during the live and the lean hog contracts.

Live/Lean Hogs Comparison

The periods corresponding to both contracts are characterized by different behavior of hog futures prices. During the live hog period, the carcass based mean futures price was $64.3/cwt, while during the lean hogs period the mean futures price was of $59.6/cwt. Futures prices do not exhibit strong trends in any of the periods as the linear trend coefficients are $-0.00001/cwt and $0.00160/cwt during the live and the lean hog periods, respectively. However, futures prices were more volatile during the lean hogs than during the live hog period. In annualized terms, the average realized volatility of the futures price was of 27.3% during 1985–1996, and of 36.6% during 1997–2005. Also, the futures price shows significant drops, followed by swift recoveries, during the lean hogs period (Figure 1).

Expected hog option returns, with and without transaction costs, differ substantially by contract period. During the live hogs contract, calls are profitable for buyers and puts are profitable for sellers, while during the lean hogs contract calls are profitable for sellers and puts are profitable for buyers (Table 3). Differences in the movements of the hog futures during the live and the lean contract period are likely to cause the contrasting option returns. During the live hog period, the hog futures experienced two major price increases with peaks in May 29, 1990 and in May 20, 1996. In contrast, during the lean hog period, two major price drops occurred in December 16, 1998 and in September 3, 2002 when the futures descended to $27.95/cwt and to $30.05/cwt, respectively.

[**PLACE TABLE 3 ABOUT HERE**]

During the live hog period, upward price movements cause more positive returns for calls, than what downward movements cause for puts. The f_{sign} statistic, shown in Table 3, indicates the percentage of observations having the same sign as the mean return. For instance, during the live hog periods 55% of the ATM call returns are positive, while only 25% of the ATM put returns are positive. In contrast, during the lean hog period, downward price movements cause more positive returns for puts than what upward movements cause for calls. During this period 33% of the ATM call returns are positive, but 37% of the ATM put returns are positive. Also, put returns, during the lean hog contract, are in general larger than call returns for the same period. Inspection of the return distributions indicate that 9% of the ATM put returns are larger than 300%, while only 4% of the ATM call returns exceed 300%.

For both levels of transaction costs, hog options absolute value returns tend to be larger during the live hog than during the lean hog period. For instance, eight zero transaction costs percentage returns and eleven off-floor trader percentage returns are closer to zero during the lean hog period. Similarly, eleven zero transaction cost contract returns and eleven off-floor trader contract returns are closer to zero during the lean hog period than during the live hog period.

Also, all but one statistically significant returns occur during the live hogs period. Results show that 33 of the 48 returns computed for live hogs are statistically significant. In contrast, only one of the 48 returns computed for lean hogs is statistically significant (Table 3). The next section presents the risk adjustment of the returns that are statistically significant.

Risk Adjustment

The test of market efficiency suggested by Jensen (1978) requires that risk-adjusted returns equal zero. Therefore, off-floor trader option returns being significantly different than zero are adjusted for risk to assess whether they are indicative of inefficiency, or whether they are consistent with some theoretical model of returns and risks. For instance, if put returns are negative on average, then risk adjustment can be used to judge whether such low returns are consequence of put mispricing or whether they are consequence of a theory-predicted risk premium that has the role of attracting speculators to the short side of the market. It is worth noting that it is unnecessary to risk adjust option returns that are not significant, because those returns do not constitute attractive speculative opportunities, even before adjusting for risk.

Two methods to adjust returns for risk are used, the Sharpe ratio (SR) and the capital asset pricing model (CAPM). SR indicates whether returns are due to a superior investment strategy or are caused by holding asset with higher risk levels. In an efficient market different assets should have similar SR's, as they returns are function of their intrinsic risk. The SR is defined as,

$$SR = \frac{E\left[r_j\right]}{Std\left[r_j\right]} \tag{4}$$

where $E[r_j]$ is the expected asset return and $Std[\cdot]$ is the standard deviation function. The SR is known to be affected by skewness in the distribution of returns. For instance, it is possible that extreme positive returns would increase the denominator proportionally more than the numerator yielding a low ratio despite the fact that those upside variations may be attractive to the investor (Goetzmann et al., 2002).

Another model to adjust returns for risk is the CAPM. This model has been widely used in studies of futures markets in general, and in studies of option markets in particular. CAPM says that the expected return on any asset can be expressed as the sum of the risk-free rate plus a compensation for the risk involved in holding the asset. That compensation is the risk premium which depends not on the asset own variance, but on the covariance of the asset rate of return with that of the market portfolio. CAPM can be written as,

$$E\left[r_j^{CAPM}\right] = r + \beta_j \; E\left[r_m - r\right] \qquad \text{where} \qquad \beta_j = \frac{Cov(r_j, r_m)}{Var(r_m)}, \tag{5}$$

where $E\left[r_j^{CAPM}\right]$ is the expected asset return predicted by CAPM, r is the risk-free interest rate, r_m is the return to the market portfolio, $Cov(\cdot)$ and $Var(\cdot)$ are the covariance and variance operators, respectively. The return to the market portfolio, r_m, is in theory a value-weighted index of all assets in the economy. The expression for β_j in (5) indicates the responsiveness of the j security to movements in the market. Intuitively, this says how much the returns of security j will change given a 1% change in the market return, r_m.

The model in equation (5) is not free of criticisms. Stein (1986) argues that some of the assumptions of CAPM are not consistent with futures markets. In particular, CAPM assumes that all investors hold the market portfolio. However, in futures markets the open interest (number of outstanding contracts) is equally divided between long and short positions, thus traders that are short can not be holding the same portfolio as traders that are long. Also, CAPM assumes that the quantity of all assets being traded is fixed, but in futures markets the number of outstanding futures contracts (the open interest) varies from day to day and is endogenously determined.

In spite of these criticisms, Dusak (1973) argues that the capital asset pricing model is remarkably robust even when some of its assumptions may not hold. Several studies have shown that the model provides an appropriate description of the relation between risks and returns (e.g., Black et al., 1972; Fama and MacBeth, 1972; Miller and Scholes, 1972). Furthermore, the CAPM model has been recently used in a series of studies on option returns (Bondarenko, 2003; Coval and Shumway, 2001). In this article, CAPM is used to determine whether significant option returns are consistent with the theory underlying this model.

Further discussion has arisen regarding the appropriate market index to use in the CAPM specification. In the model the term r_m represents the returns on the market portfolio, which in theory is a value-weighted index of all assets in the economy. Since this variable is not observable, Dusak (1973) used the Standard and

Poor Index of 500 Common Stocks (S&P500). However, Carter et al. (1983) criticized the use of this index alone as it does not directly include agricultural commodities. The authors note that agricultural commodities are indirectly included in the S&P500 through the publicly traded firms that are in the S&P index and hold these commodities in their inventories. These authors suggested using an equally-weighted combination of the S&P500 and the Dow Jones commodity futures. They argued that this scheme would provide a better representation of the importance of commodities in the economy.

Later Marcus (1984) argued that Carter et al. (1983) overestimated the importance of agricultural commodities in the economy. Marcus (1984) comparing the value of agricultural farm assets to the value of the household sector net wealth and the gross farm income with the national income concludes that the appropriate weight for the commodities in a market index should be roughly one-tenth. The author notes that the estimated β's are an increasing function of the weight of the commodities in the index. This is because the greater the participation of commodities in the market index, the higher the correlation of any single commodity return with the index return.

In this research, returns to the Commodity Research Bureau (CRB) index futures are used as proxy for the market return in the CAPM.[4] The CRB index tracks the price movements of a wide range of commodities, and it is used here to proxy changes in the value of the portfolio of a decision-maker investing in commodity markets. The CRB index futures, designed by Reuters, is traded at the New York Board of Trade. It includes 17 contracts of the following types of commodities energy, grains, industrials, livestock, precious metals and softs. The grain and energy categories each represent 17.6% of the value of the index. The CRB index returns are computed buying the index on the same day the option is purchased and sold on the same day the option expires.

In order to test the observed returns against CAPM, the Jensen's alpha is computed as,

$$\alpha_{i,j} = r_{i,j} - E\left[r_j^{CAPM}\right], \tag{6}$$

where $r_{i,j}$ is the ith return for the jth asset (*i.e.*, $r_{i,j}$ is defined as $r_j \equiv r_{p,K}$ and as $r_j \equiv r_{c,K}$). Jensen's α is a risk-adjusted measure of the returns that the asset is earning above (or below) the returns predicted by CAPM — the excess returns. Therefore, if observed returns are consistent with CAPM, the average α should not be different from zero. Given possible asymmetries in the distribution of excess returns, bootstrapped confidence intervals are constructed to test whether SR's and excess returns α's equal zero. Confidence intervals are constructed using the bootstrapping techniques described above.

The risk adjustment for off-floor traders call and put returns during the live hog period is presented in Table 4. Option returns are highly variable, thus the SR's indicate that returns per unit of risk are low.

Sharpe ratios range from -1.29 to 0.46, with the ratio for deep-out-the-money puts the only one larger than unity. Furthermore, the SR's confidence intervals show that all option categories having significant expected returns also exhibit SR's that are significantly different from zero.

[PLACE TABLE 4 ABOUT HERE]

Similarly, the CAPM is rejected for seven of the eight options categories yielding statistically significant expected returns (Table 4). For instance, alpha's for calls with moneyness $k = 0.94$ and $k = 1.00$ and for the pooled call return indicate that observed returns are significantly larger than returns predicted by CAPM, according to the options' β's. Also, all puts having statistically significant returns have statistically significant excess returns α's. Using the SR and the CAPM to adjust returns suggests that some option categories yielded significant excess returns during the period 1985 – 1996, and that speculative opportunities may have existed. Results also suggest that the contract redesign has improved the efficiency of the hog option market.

Straddle and Strangle Returns

This section investigates simulated option returns to buying straddles and strangles formed by purchasing of an equal number of calls and puts with the same time to expiration and the same or different strike prices. Straddles have been used in several studies of options market efficiency (e.g., Szakmary et al., 2003; Simon, 2001), but strangles have not. The advantage of using both straddles and strangles is that this allows assessing the pricing ability of options with a range of moneyness, while straddles provide information for ATM options only. Also, the simulations of long straddle and strangle strategies complement the strategy of buying and holding puts and calls individually because straddles and strangles do not require a forecast on the direction of futures price movements. Straddle and strangles are non-directional trades and profits from futures price movements in either direction. For instance, if the futures increase substantially the call price will increase more than the put price falls, and the straddle value will increase. However, straddles and strangles will experience losses if the futures does not move substantially in either direction. It is worth noting that these strategies have a limited downside risk because the maximum possible loss of straddles and strangles are the premiums paid to purchase the options. Straddles and strangles also profit from increases in implied volatility. The value of calls and puts increases with IV, thus if IV increases after the position has been initiated trader can offset the straddle or strangle at a price higher that the purchase price.[5]

Long straddles are formed by purchasing one nearest-to-the-money call and one nearest-to-the-money put and held until the options expiration. Additionally, two types of strangles are simulated, out-of-the-money and deep-out-the-money strangles. Out-the-money strangles are formed by purchasing calls with moneyness $k = 1.03$ and puts with moneyness $k = 0.97$, and deep-out-the-money strangles are formed by purchasing calls with moneyness $k = 1.06$ and puts with moneyness $k = 0.94$

Returns to long straddle and strangle positions are computed in percentage terms as,

$$r_k = \left(\frac{c_{K_1,T} + p_{K_2,T}}{c_{K_1,t} + p_{K_2,t} + tc} - 1 \right) * 100. \quad (7)$$

Similarly, straddles and strangle returns are expressed in dollars per contract as,

$$r_k = \left(c_{K_1,T} + p_{K_2,T} - c_{K_1,t} - p_{K_2,t} - tc \right) * 400, \quad (8)$$

where $c_{K_1,T} = \max(F_T - K, 0)$ and $p_{K_1,T} = \max(K - F_T, 0)$ are, respectively, the premiums for calls and puts at expiration. The purchase price of calls and puts at time t is denoted $c_{K_1,t}$ and $p_{K_2,t}$, respectively. For the straddles $K_1 = K_2$, while for OTM and DOTM strangles $K_1 > K_2$. Similar to the trading of calls and puts, straddles and strangles per contract transaction costs, tc, are considered to be 1/2 tick per option, plus 1/2 tick to offset the futures once the option that expires ITM is exercised, plus a broker's commission of \$50 for the trading of both options plus a \$2 commission to exercise the ITM option.[6] Therefore, the total per contract transaction costs of a straddle or strangle strategy is of \$15 and \$67, for floor and off-floor traders, respectively.

Straddle and strangle strategies profit from increases in implied volatility. For instance, if IV increases once the position has been established the value of both calls and puts will raise and the strategy can be sold at a profit. Therefore, it might be wise to buy straddles or strangles when the trader expects an increase in IV. In order to test whether any mispricing in option premiums may be exploited, different entry rules that increase the possibilities of profitable trades are simulated. First, straddles and strangles are initiated with options having one month to expiration regardless of volatility levels. Second, straddles and strangles are initiated with options having one month to expiration on days where the 30-day moving average of realized futures volatility (RV) is below average. This strategy would profit from a mean-reverting volatility behavior. Indeed, inspection of the RV and of IV patterns through the sample indicates cycles around a long term mean. Realized volatility is computed as the standard deviation of the continuously compounded daily returns calculated as the log of the ratio of the futures price at t and at $t-1$. Realized volatilities are annualized by multiplying the above volatility by the square root of 252, which is the typical number of trading days per year. Third, straddles and strangles are initiated with options having one month to expiration on days where the ATM implied volatility is below the sample average implied volatility. Similar to the RV decision rule, this strategy will generate profits when IV increases once the position has been established. The goal of the IV decision rule is to enter the straddle and strangle trades when IV is relatively low.[7] Implied volatilities are computed using the Black's future options pricing model for the nearest-to-the-money call and the nearest-to-the-money put with approximately 30 calendar days to expiration. At-the-money IV's are constructed by averaging the IV's of calls and puts. For all simulated strategies straddle and strangle positions are held until the options' expiration date. Similar trading decision rules have been used in previous option research studies (e.g., Simon, 2001)

[PLACE TABLE 5 ABOUT HERE]

For brevity, only zero-transaction costs and off-floor traders' returns are presented. Returns for floor-traders are in between the presented results. Simulations results are analyzed for the whole sample period and, in the next section, separately for the live and for the lean hog periods. Results for the whole sample are shown in Table 5. Results show that returns to buying straddles and strangles systematically, before and after transaction costs, are not economically important and not statistically significant. When volatility is not used to trigger the trading positions, after transaction costs percentage returns range from 3.9% to 19.0% and after transaction costs contract returns range from $-68.1 to $1.6. When the trigger to initiate the positions is a below average 30-day moving average RV, after transaction costs dollar gains are negative or positive but small. The largest returns are obtained when the criterion to enter the straddles and strangles is a below average IV. In this case returns increase with respect to the other rules, and returns from OTM strangles are the largest. However, while some percentage returns appear large, neither percentage nor dollar returns are statistically significant with the only exception of zero transaction cost percentage returns for straddles.

Straddle and Strangle Returns for Live and Lean Hogs

Straddle and strangle returns split into live and lean hog periods are presented in Table 6.[8] Straddle and strangle returns tend to be small and non-significant for both live and the lean hog periods. When volatility is not used as a trading rule, the largest returns is the one for live OTM strangle, with a percentage return of -35.1% and a contract return of $-143.0. Employing RV to determine the trading of straddles and strangles tends to produce small losses, on a per contract basis, during both periods. In contrast, when IV is used to decide entering the market small gains are achieved. However, in any case are the returns statistically significant, indicating that these option combinations do not yield consistent speculative gains during either period.

Straddle and strangle returns are at odds with individual calls and puts returns during the live hog period. During this period individual calls and puts in some moneyness categories yield significant excess returns.

However, when calls and puts are combined into straddles and strangles absolute value returns are fairly small. This contrasting result can be due to the fact that call returns tend to be positive and put returns tend to be negative during the lean hog period, when both options are combined positive and negative returns offset each other. Results of this section support the idea that combinations of options do not yield consistent speculative gains during any of the periods analyzed. Next, the effects of several market conditions on option returns are described.

[**PLACE TABLE 6 ABOUT HERE**]

In order to investigate the process of returns thoroughly, the effects of time, time of year and the release of the Hogs and Pigs Report (HPR) on call, put, straddle and strangle returns are quantified using regression analysis.[9] For brevity, these results are not presented, but are available from the authors upon request. The described effects can influence option returns given that market behavior might change over time as traders learn and liquidity increases. In such a case, option returns would tend to zero overtime. Furthermore, futures prices volatility varies throughout the year as information flows more or less often into the market, and it is also known that market participants follow closely the information contained in the HPR's (e.g., Isengildina-Massa et al., 2006; Egelkraut and Garcia, 2006). If any of these variables have a substantial effect, hog option returns would vary systematically.

Results indicate that independent variables explain little of the return variability as coefficients of determination are low and estimated parameters are not statistically significant. For instance, the estimated models indicate no significant linear or quadratic time trends in option returns and no differences in returns among quarters. The release of the HPR reduces the return of call and put options, probably because option sellers charge a higher price fearing the market moves against them as a consequence of the information contained in the report. However, the HPR announcement effect is not significant. Regression results indicate that the pricing ability of the hog options market is stable through time and time of year, and that it is not affected by the release of the HPR's.

Overall, results presented indicate that different trading strategies for calls, puts, straddles and two types of strangles do not provide consistent speculative opportunities. Comparing live and lean hog option returns indicates that some option categories yielded significant risk adjusted returns during the live hog period, but not during the lean hog period. These findings indicate that the hog option market is efficient and that the contract redesign helped to improve the option pricing ability of the market.

Conclusion

This article evaluates the efficiency of the hog options market and the effect of the hog contract redesign on efficiency. Empirical returns from different trading strategies were computed using a history of 21 years of futures and option prices. Analyzing the full sample, we find that observed option returns are highly variable and not statistically different from zero. Contract returns are small and do not appear to yield economically significant profits. These findings hold for the trading of calls, puts, straddles and two types of strangles and indicate that the hog option market is efficient. The comparison of the live/lean hog contracts shows that some moneyness categories of calls and puts yield excess risk-adjusted profits during the live hog period, but not during the lean hog period. These results suggest that the hog contract redesign improved the efficiency of the hog options market.

Our findings agree with those of McKenzie et al. (2007) who concluded that the hog options market is efficient for an off-floor trader. Szakmary et al. (2003) and Egelkraut and Garcia (2006) find that the IV of hog options is a biased forecast of the futures realized volatility, thus indicating option mispricing. Results of this study complement those of Szakmary et al. (2003) and Egelkraut and Garcia (2006) given that our findings indicate that any possible mispricing of hog options is not large enough to generate consistent speculative profits.

Also, our results are at odds with the hog producers' perceptions that hog option premiums are too high. However, it is not uncommon for agricultural producers to miscalibrate the actual futures price distribution (e.g., Eales et al., 1990; Kenyon, 2001). For instance, if producers expect a lower than actual price volatility they will see options premiums as too high. Similarly, if the producer's subjective probability distribution is more skewed toward higher prices than the actual distribution, producers will see put options as too expensive. Misperceptions such as these have been proposed formally by Tversky and Kahneman (1974). Results of this study suggest that option mispricing claims are caused by biases in the producer's perceptions of futures price distribution.

Notes

[1]The settlement committee, also called pit committee, is composed of a group of designated traders that propose settlement option prices taking into account their order books and other market information.

[2]Trading strategies with 90 and 120 day options were also simulated, but not reported. Results from those strategies do not differ substantially from the ones reported here and are available upon request

[3]Note that while computations of contract returns do not change the sign of the return for individual options, they do change their magnitudes. As a consequence, some expected returns may have different signs when expressed in percentage than when expressed in dollar terms. For instance, consider that four options are purchased three at a premium of $1 and one at a premium of $10. Assume that the three options purchased by $1 expire OTM and that the option purchased at $10 expires ITM being worth $15. In this example, the average percentage return from these four options is -62.5%, (=(-100 - 100 - 100 + 50)/4), but the contract return is $200, (=(-400 - 400 - 400 + 2000)/4).

[4]In order to explore the impacts of possible mispecifications, returns predicted by CAPM were also computed using the S&P 500 index as a proxy for the returns to the market portfolio, r_m. Results obtained were qualitatively the same as the ones presented in this article and CAPM-predicted returns were significantly different from observed returns for the same moneyness categories as the ones shown in Table 4.

[5]Note that initially a straddle is a delta-neutral strategy given that, by the put-call parity, call and put deltas are equal of opposite sign. In this study, however, the strategies are simulated as buy-and-hold and not rebalanced through the holding period. Therefore, the delta of the straddle position, formed by the sum of the call and the put deltas, can become positive or negative as one of the options moves into the money given the movements of the futures price.

[6]Broker's commission for individual calls and puts are considered to be $30, for the case of straddle and strange strategies these commissions are considered to be $50 to mimic the usual brokers practice of charging smaller marginal commissions for a larger the number of trades.

[7]Straddles and strangles where also initiated when RV and IV were below their 40th and 30th percentiles. Such strategies did not produce statistically significant profits

[8]For brevity, only off-floor trader returns are presented. Zero-transaction cost and floor-trader's returns lead to conclusions similar to the ones presented and are available upon request.

[9]The HPR's, developed and released by the USDA, inform about U.S. pig production for major states and for the whole country, including inventory numbers by class, weight groups, value of hogs and pigs, farrowings, and farrowing intentions. The schedule for the release of the HPR during the sample period is the following: from February 1985 through December 1999 reports were issued four times a year (March, June, September and December); from January 2001 through September 2003 reports were issued monthly; and after September 2003 the report schedule returned to its previous quarterly basis.

References

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

Black, F., M. Jensen, and M. Scholes . "The capital asset pricing model: Some empirical results." *Studies in the Theory of Capital Markets*. M. Jensen, ed. New York: Praeger, 1972.

Bollen, N. P. B. and R. E. Whaley. "Does net buying pressure affect the shape of implied volatility functions?" *Journal of Finance* 59(2004):711–753.

Bondarenko, O. "Why are put options so expensive?" Paper Presented at the American Finance Association, San Diego, CA. April 2003. http://ssrn.com/abstract=375784.

Carter, C. A., G. C. Rausser, and A. Schmitz. "Efficient asset portfolios and the theory of normal backwardation." *Journal of Political Economy* 91(1983): 319—331.

Chan, L. H. and D. D. Lien. "Cash settlement and price discovery in futures markets." *Quarterly Journal of Business and Economics* 40(2001): 65–77.

Chiras, D. P. and S. Manaster. "The information content of option prices and a test of market efficiency." *Journal of Financial Economics* 6(1978):213–234.

Coval, J. D. and T. Shumway. "Expected option returns." *Journal of Finance* 56(2001):983–1009.

Ditsch, M. W. and R. M. Leuthold. "Evaluating the hedging potential of the lean hog futures contract." OFOR Working Paper 96-03, University of Illinois At Urbana-Champaign, 1996.

Dusak, K. "Futures trading and investor returns: An investigation of commodity market risk premiums." *Journal of Political Economy* 81(1973):1387—1406.

Eales, J. S., B. K. Engel, R. J. Hauser, and S. R. Thompson. "Grain price expectations of Illinois farmers and grain merchandisers." *American Journal of Agricultural Economics* 72(1990):701—708.

Egelkraut, T. M. and P. Garcia. "Intermediate volatility forecast using implied forward volatility: The performance of selected agricultural commodity options." *Journal of Agricultural and Resource Economics* 31(2006):508—528.

Fama, E. "Efficient capital markets: A review of theory and empirical work." *Journal of Finance* 25(1970):383–417.

Fama, E. "Market efficiency, long-term returns, and behavioral finance." *Journal of Financial Economics* 49(1998):283–306.

Fama, E. and J. MacBeth . "Risk, return and equilibrium: Empirical tests." Manuscript, University of Chicago, 1972.

Ferguson, M. F. and S. C. Mann. "Execution costs and their intraday variation in futures markets." *Journal of Business* 74(2001):125–160.

Frank, J. and P. Garcia. "Measuring liquidity costs in agricultural futures markets." *Proceedings of the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management.* 2007.

Galai, D. "Empirical test of boundary conditions for CBOE options." *Journal of Financial Economics* 6(1978):187–211.

Goetzmann, W. N., J. E. Ingersoll Jr., M. I. Spiegel, and I. Welch. "Sharpening Sharpe ratios." Working paper, Yale School of Management, 2002.

Greene, W. G. *Econometrics Analysis* (3rd ed.). Prentice Hall, 1997.

Hauser, R. J. and Y. Liu. "Evaluating pricing options models for options on futures." *Review of Agricultural Economics* 14(1992):23—32.

Irwin, S. H. "Research directions in commodity options—academic and practitioner views." *Review of Futures Markets* 9(1990):134—155.

Isengildina-Massa, O., S. H. Irwin, and D. L. Good. "The value of USDA situation and outlook information in hog and cattle markets." *Journal of Agricultural and Resource Economics* 31(2006): 262–282.

Jensen, M. "Some anomalous evidence regarding market efficiency." *Journal of Financial Economics* 6(1978):95–101.

Kenyon, D. E. "Producer ability to forecast harvest corn and soybean prices." *Review of Agricultural Economics* 23(2001):151—162.

Kimle, K. and M. Hayenga. "Cash settlement as an alternative settlement mechanism for the live hog futures contract." Staff General Research Papers 11639, Department of Economics, Iowa State University, 2004.

Lawrence, J. D. and G. Grimes. "Production and marketing characteristics of U.S. pork producers, 2006." Iowa State University Working Paper # 07014, June 2007.

Lien, D. and Y. K. Tse. "A survey on physical delivery versus cash settlement in futures contracts." Working paper, Singapore Management University, 2003.

Locke, P. R. and P. C. Venkatesh. "Futures markets transaction costs." *Journal of Futures Markets* 17(1997):229–245.

Manfredo, M. M., R. M. Leuthold, and S. H. Irwin. "Forecasting fed cattle, feeder cattle, and corn cash price volatility: The accuracy of time series, implied volatility, and composite approaches." *Journal of*

Agricultural and Applied Economics 33(2001):523–538.

Manfredo, M. M. and D. R. Sanders. "The forecasting perfomance of implied volatility from live cattle options contracts: Implications for agribusiness risk management." *Agribusiness* 20(2004):217—230.

Marcus, A. J. "Efficient asset portfolios and the theory of normal backwardation: A comment." *Journal of Political Economy* 92(1984):162–164.

McKenzie, A., M. Thomsen, and J. Phelan. "How do you straddle hogs and pigs? Ask the greeks!" *Applied Financial Economics* 17(2007):511–520.

Miller, M. and M. Scholes. "Rates of return in relation to risk: A reexamination of some recent findings." *Studies in the Theory of Capital Markets.* M. Jensen, ed. New York: Praeger, 1972.

Myers, R. J., S. D. Hanson, J. Lai, and H. Wang (1996). "Volatility based tests for informational efficiency on commodity options markets." Paper presented at the NCR-134 Conference on Applied Commodity Price Analysis, Chicago, IL, April 1996.

Simon, P. "Implied volatility forecasts in the grains complex." *Journal of Futures Markets* 22(2001):959–981.

Stein, J. L. *The Economics of Futures Markets*. Basil Blackwell, 1986.

Szakmary, A., E. Ors, J. K. Kim, and W. N. Davidson III. "The predictive power of implied volatility: Evidence from 35 futures markets." *Journal of Banking and Finance* 27(2003):2151—2175.

Tversky, A. and D. Kahneman. "Judgment under uncertainty: heuristics and biases." *Science* 185(1974):1124–1131.

Williams, E. *The compatibility quotient.* Technical report, Top Producer, November, 2003.

Table 1. Live and Lean Hog Contract Specifications Comparison

	Live Hog Contract	Lean Hog Contract
Size of Contract:	40,000 lbs. live-weight	40,000 lbs. carcasses
Settlement:	Physical Delivery	Cash Transfer
Weight Range:	230 - 260 pounds	170 - 191 pounds (carcass weight)
Approx. Head/Contract:	173 - 153 (avg. 163)	235 - 209 (avg. 221)
Months:	Feb, Apr, Jun, Jul, Aug, Oct, Dec	Feb, Apr, May, Jun, July, Aug, Oct, Dec
Minimum Price Fluctuation:	2 cents per 100 lb.	2 cents per 100 lb.
Limit:	1 cents per lb.	1 cents per lb.
Options Months:	Feb, Apr, Jun, Jul, Aug, Oct,	Feb, Apr, May, Jun, Jul, Aug, Oct, Dec and serial months Jan, Mar, Nov
Options Expiration	Two - three weeks before the futures last trading day	On the tenth business day of the contract month

Note. Contract specifications are taken from the CME Rulebook, Chapter 152 Lean Hog Futures and Chapter 152A Options on Lean Hog Futures and from the Management Marketing Memo, MMM 343, Department of Agricultural Economics, Clemson University.

Table 2. Zero Transaction Cost, Floor-Trader and Off-Floor Trader Returns for Hog Futures Options Across Moneyness Categories, 2/1/1985 – 12/31/2005

	Calls by Moneyness						Puts by Moneyness					
	0.94	0.97	1.00	1.03	1.06	Pooled	0.94	0.97	1.00	1.03	1.06	Pooled
Panel A: Zero transaction cost returns												
Mean Return(%)	13.8	3.6	20.8	15.5	16.9	15.4	42.1	7.2	15.8	4.2	-18.3	14.8
Mean Return ($/contract)	149	-11	89	51	5	51	-8	-25	31	35	-249	-22
Std Dev (%)	90.3	104.7	159.3	218.4	313.1	210.3	682.2	301.5	224.5	142.3	90.5	391.5
Skewness	0.9	0.8	1.3	2.2	3.4	3.4	6.7	5.0	3.6	2.1	1.6	9.5
Panel B: Floor trader returns												
Mean Return (%)	13.3	2.5	18.5	11.4	6.6	11.0	28.8	3.2	13.5	3.0	-18.8	9.7
Mean Return ($/contract)	139	-21	79	41	-5	41	-18	-35	21	25	-259	-32
Panel C: Off-floor returns												
Mean Return(%)	10.6	-1.0	11.9	0.4	-15.5	0.5	0.6	-7.6	6.9	-0.4	-20.7	-2.3
Mean Return ($/contract)	107	-53	47	9	-37	9	-50	-67	-11	-7	-291	-64
n	55	80	147	157	130	569	136	135	141	79	60	551

Note. Moneyness is defined by $k = K/F_t$. Thus, 0.94 and 0.97 indicates ITM calls and OTM puts; 1.03 and 1.06 indicates OTM calls and ITM puts; 1.00 indicates ATM calls and puts. Per contract returns are computed as $r_{p,K} * c_{K,t} * 400$ and $r_{c,K} * p_{K,t} * 400$ for calls and puts, respectively. For hog options, contract size is 40,000 pounds, thus a contract equals 400 cwt.

Zero transaction cost returns are computed using settlement prices only and do not include any transaction costs. Floor trader returns include transaction costs of $10/contract (1/2 tick to establish the position plus 1/2 tick to offset the futures once the option has been exercised; for the hog futures contract 1 tick represents $10). Off-floor trader returns include transaction costs of $42/contract (floor trader's transaction costs plus broker's commissions).

Confidence intervals for the mean returns were bootstrapped using 2,000 repetitions. All confidence intervals for the mean returns presented in the table included zero. The number of observations is denoted by n. Pooled refers to the statistics computed by pooling across moneyness categories and weighting by observations.

Table 3. Zero Transaction Cost and Off-Floor Trader Returns for Hog Options During the Live and the Lean Hog Periods, 2/1/1985 – 12/31/2005

	Calls by Moneyness						Puts by Moneyness					
	0.94	0.97	1.00	1.03	1.06	Pooled	0.94	0.97	1.00	1.03	1.06	Pooled
Live Hog Period: 1985–1996												
Zero transaction cost returns												
Mean Ret. (%)	38.6*	43.3*	63.0*	49.5	94.2	61.3*	-84.5*	-41.5	-34.5	-25.2	-34.7*	-45.5*
Mean Ret. ($/contract)	497*	348*	294*	153	81	240*	-111*	-135*	-193*	-173	-398*	-188*
Off-floor trader returns												
Mean Ret. (%)	34.1*	36.0*	49.3*	29.3	33.6	37.0*	-89.0*	-52.8	-40.3*	-28.9	-36.9*	-51.3*
Mean Ret. ($/contract)	455*	306*	252*	111	39	198*	-153*	-177*	-235*	-215	-440*	-230*
f_{sign} (%)	65	62	55	33	28	45	98	91	75	66	68	81
n	23	29	53	51	47	203	44	43	48	35	28	198
Lean Hog Period: 1997–2005												
Zero transaction cost returns												
Mean Ret. (%)	-3.96	-18.95	-2.98	-0.88	-26.83	-10.09	102.62	30.01	41.76	27.58	-3.92	48.65*
Mean Ret. ($/contract)	-102	-215	-26	2	-38	-53	41	26	146	201	-119	70
Off-floor trader returns												
Mean Ret. (%)	-6.4	-22.0	-9.2	-13.5	-43.3	-19.7	43.4	13.5	31.3	22.2	-6.5	25.2
Mean Ret. ($/contract)	-144	-257	-68	-40	-80	-95	-1	-16	104	159	-161	28
f_{sign} (%)	63	65	67	77	89	74	13	24	37	43	53	29
n	32	51	94	106	83	366	92	92	93	44	32	353

Note. Moneyness is defined by $k = K/F_t$. Thus, 0.94 and 0.97 indicates ITM calls and OTM puts; 1.03 and 1.06 indicates OTM calls and ITM puts; 1.00 indicates ATM calls and puts. Per contract returns are computed as $r_{p,K} * c_{K,t} * 400$ and $r_{c,K} * p_{K,t} * 400$ for calls and puts, respectively.
Zero transaction cost returns are computed using settlement prices only and do not include any transaction costs. Off-floor trader returns include transaction costs of $42/contract (1/2 tick to establish the position plus 1/2 tick to offset the futures once the option has been exercised plus broker's commissions).
Asterisks (*) indicates that the bootstrapped 95% confidence interval for the mean return, constructed using 2,000 repetitions, does not include zero. The f_{sign} statistic indicates the percentage of observations having the same sign as the mean. The number of observations is denoted by n. Pooled refers to the statistics computed by pooling across moneyness categories and weighting by observations.

Table 4. Risk Adjustment for Hog Options Off-floor Trader Returns During the Live Hog Period, 2/1/1985 – 12/31/1996

	Calls by Moneyness						Puts by Moneyness					
	0.94	0.97	1.00	1.03	1.06	Pooled	0.94	0.97	1.00	1.03	1.06	Pooled
Mean Ret. (%)	34.1*	36.0*	49.3*	29.3	33.6	37.0*	-89.0*	-52.8	-40.3*	-28.9	-36.9*	-51.3*
Std Dev(%)	74.0	98.3	148.6	194.7	256.7	179.1	69.1	173.2	118.2	89.4	67.3	115.0
Sharpe Ratio	0.46*	0.37*	0.33*	0.15	0.13	0.21*	-1.29*	-0.30	-0.34*	-0.32	-0.55*	-0.45*
$E[r^{CAPM}]$ (%)	1.5	20.7	0.2	-3.6	9.3	0.0	-2.5	2.1	-0.7	1.4	7.1	-0.1
β	8.8	19.0	-1.8	8.0	-24.0	-0.5	-6.6	27.3	5.4	-13.1	-15.0	2.8
$\overline{\alpha}$	32.7*	15.2	49.1*	33.0	24.3	37.0*	-86.5*	-54.9	-39.6*	-30.3	-44.0*	-51.3*
n	23	29	53	51	47	203	44	43	48	35	28	198

Note. The CAPM predicted return for each option is denoted $E[r_j^{CAPM}]$, the CRB commodity index is used as a proxy for the return on the market portfolio r_m and $\overline{\alpha}$ is the average excess returns. Asterisks (*) indicates that the bootstrapped 95% confidence interval for the statistic, constructed using 2,000 repetitions, does not include the zero.

Table 5. Zero Transaction Cost and Off-Floor Trader Returns for Straddle, Strangle and Out-the-money Strangle with Three Trading Decision Rules, 2/1/1985 – 12/31/2005

	No volatility rules buy and hold systematically		RV is below the 30 day MA		IV is below the sample mean	
	%	$/contract	%	$/contract	%	$/contract
Straddle						
Zero transaction cost returns	10.4	68.6	7.9	23.3	20.4*	186.2
Off-floor trader returns	3.9	1.6	1.6	-43.7	12.9	119.2
n	141	141	95	95	80	80
Strangle						
Zero transaction cost returns	18.5	-1.1	29.3	12.6	46.8	181.8
Off-floor trader returns	5.3	-68.1	13.4	-54.4	28.6	114.8
n	125	125	78	78	74	74
OTM Strangle						
Zero transaction cost returns	54.6	47.2	79.9	78.6	119.2	236.8
Off-floor trader returns	19.0	-19.8	34.9	11.6	63.0	169.8
n	92	92	60	60	53	53

Note. Zero transaction cost returns are computed using settlement prices only and do not include any transaction costs. Off-floor trader returns include transaction costs of $67/contract (1/2 tick per option to establish the position plus 1/2 tick to offset the futures once the option that expires ITM has been exercised plus broker's commissions).
Asterisks (*) indicates that the bootstrapped 95% confidence interval for the mean return, constructed using 2,000 repetitions, does not include the zero.

Table 6. Off-Floor Trader Returns for Straddle, Strangle and Out-the-money Strangle with Three Trading Decision Rules for the Live and the Lean Hog Periods

	No volatility rules buy and hold systematically		RV is below the 30 day MA		IV is below the sample mean	
	%	$/contract	%	$/contract	%	$/contract
Straddle						
Live Mean	4.7	31.9	-3.7	-62.7	5.6	39.7
n	47	47	47	47	47	47
Lean Mean	3.6	-13.5	6.7	-25.0	23.2	232.3
n	94	94	48	48	33	33
Strangle						
Live Mean	-2.2	2.9	-1.2	-41.1	5.6	77.3
n	27	27	16	16	15	15
Lean Mean	7.4	-87.7	17.2	-57.8	34.4	124.3
n	98	98	62	62	59	59
OTM Strangle						
Live Mean	-35.1	-143.0				
n	15	15				
Lean Mean	29.5	4.2		†		
n	77	77				

Note. Live Mean and Lean Mean are the average return during 2/1/1985 – 12/31/1996 and during 1/1/1997 – 12/31/2005, respectively. Returns include transaction costs of $67/contract (1/2 tick per option to establish the position plus 1/2 tick to offset the futures once the option that expires ITM has been exercised plus broker's commissions).
Asterisks (*) indicates that the bootstrapped 95% confidence interval for the mean return, constructed using 2,000 repetitions, does not include the zero.
† The number of live hog options meeting the trading decision rules was too small to allow for a meaningful comparison of the options market efficiency in both periods.