Has the Performance of the Hog Options Market Changed?

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Abstract

The hog option contract has served as a risk management tool for the pork industry for more than 20 years. However, very limited information exists about how this market behaves and how it was affected by the contract redesign of 1996. This paper evaluates the efficiency of hog options markets comparing its pricing function during the live hog contract period to the lean hog contract period. Trading returns are computed and adjusted for risk using the Sharpe ratio and the Capital Asset Pricing Model. When the whole sample period is analyzed, results indicate that no profits can be made by taking either side of the hog options markets. However, analyzing the live and the lean hog contracts separately, some evidence suggest that opportunities for speculative profits existed during the live hog contract period. These conclusions are not driven by the extreme price movements in the futures price occurred during late 1998. Further research should investigate whether general futures price movements are responsible for these large returns.

Keywords: hog options, mispricing, trading returns, market efficiency

1 Introduction

Recently, concerns about the pricing of options on live/lean hog futures have been raised. Szakmary et al. (2003) and Egelkraut (2004) found implied volatility to be a biased forecaster of subsequent realized volatility. Since option prices are function of the underlying asset price volatility, a biased forecast indicates that options are either over- or underestimating the volatility of the futures price. Consequently, abnormal returns potentially can be made by trading these options because option prices would not be reflecting the true value of the options. The concerns surfaced after the Chicago Mercantile Exchange

(CME) revised its hog contracts in an effort to improve performance. The hog contract was renamed and the settlement procedure changed from physical delivery to cash settlement in 1996. The underlying asset of the futures contract was also changed from a live hog basis to a carcass hog basis. Following structural changes in the hog production industry, the contract redesign was aimed to improve the price discovery and hedging functions of hog futures and options.

For more than 20 years, the hog option contract has served as an important risk management tool in the pork industry. However, limited information exists about how this market behaves and how it was affected by the contract changes in 1996. This lack of information is surprising since evidence exists that the hog futures contract was affected by the change from physical delivery to cash settlement. Using data from 1984 to 1999, Chan and Lien (2001) compared the live to lean hog futures contract. The authors found that the price discovery ability of the hog futures contract had diminished after 1996. However, in a later study the authors used the volatility implied in options prices, from 1/3/1995 to 10/14/1998, to evaluate the impact of cash settlement on futures price volatility. The authors concluded that hog futures prices has become less volatile after the adoption of cash settlement, thus improving the risk management function of the contract. The authors warn that other structural changes also affected the pork industry during their sample period (Chan and Lien 2004). Changes in settlement procedures are also known to have changed the behavior of the CME feeder cattle contract, which underwent modifications in the mid 1980's (Chan and Lien 2002).

Options and futures markets are closely intertwined by arbitrage relationships. Therefore, it is likely that the redesign of the futures contract has also affected the behavior of the option contract. A key function of option markets is the ability to correctly set option premiums. For example, if option premiums are too high, producers and/or processors who hedge the value of their products may lose substantial amounts of money when using options. It is the equivalent of buying expensive insurance, and if this in-

surance is expensive enough, the cost can offset (or more than offset) the benefits of reducing risks.

Option mispricing may persist in equilibrium because margin requirements of short positions impose limits to arbitrage (Shleifer and Vishny 1997; Liu and Longstaff 2004). When margin calls are large enough, investors may not have the funds to meet them, and be forced to liquidate their positions at a loss. Options mispricing can be analyzed formally using the concept of market efficiency. There are two basic approaches to testing options market efficiency. The first approach computes returns to different trading schemes using historical option prices. Returns are computed using a riskless trading strategy or raw returns are adjusted for risk using a theoretical model. In general, the efficient market hypothesis (EMH) requires that expected risk-adjusted returns equal zero. The second approach is based on the prediction that implied volatility (IV) should be an unbiased predictor of subsequent realized volatility (RV) under market efficiency, otherwise the options market may not correctly price options. The IV can be obtained by inverting a given pricing model and solving for the standard deviation.

While there have been numerous studies of the efficiency of financial options markets (e.g., Coval and Shumway 2001; Bondarenko 2003; Bollen and Whaley 2004), the efficiency of agricultural options markets has been largely overlooked. Only Szakmary et al. (2003) and Egelkraut (2004) investigated hog options market efficiency, both using the implied volatility approach. Implied volatility tests of options market efficiency have two important limitations. First, estimation of implied volatility requires specification of a theoretical model. Thus, researchers need to commit to a given pricing model. Both of the aforementioned studies used Black's (1976) formula for European futures options. Second, the IV approach does not allow direct testing of the efficient market hypothesis because trading returns are not computed and transaction cost are not included. These costs are known to have a substantial impact on net trading returns (Lence 1996) and to change over time (Park 2005). Therefore, mis-specification of the theoretical pricing

model and the omission of transaction costs may bias the results of efficiency tests in previous studies. By comparison, the simulated trading approach is model-free and allows direct testing of the efficient market hypothesis because returns can be computed and tested statistically.

The objective of the proposed study is to test the efficiency of the hog options market, and to compare the pricing function of this market during the live hog contract period with the lean hog contract period. Trading returns will be computed and the effect of transaction costs will be assessed. Results of this study will improve the understanding about the impact of changes in contract specification on the performance of options markets.

2 Data and Methods

Daily settlement prices for American hog futures options are used in this study. Option and futures data come from the CME and from Barchart. Short-run interest rate is proxied by the 3-month Treasury Bill rate. The interest rate series is from the Federal Reserve Bank. All data cover the period 2/1/1985 to 12/31/2005.

The CME lists eight hog options and futures contract a year; these are February, April, May, June, July, August, October and December. While most of the option theory is developed for European-type options, this study is not affected by differences in pricing between American and European options because no theoretical pricing model will be used.

Daily settlement option prices are used since these do not suffer from nonsynchronous/ stale trading, and are less likely to have rounding errors or to violate basic non-arbitrage restrictions than other daily prices, such as closing or open prices. This is because settlement prices are scrutinized at two different levels of control at the close of each trading day. First, prices are proposed by the settlement committee members. In proposing

settlement prices committee members exert a mutual control over each other, since they are immersed in a conflict of interests. Settlement prices are used by the Clearing Corporation to compute the margin requirements. These margins determine the amount of money traders must maintain on deposit, and in some situations margins calls might drive traders into bankruptcy. Secondly, prices are checked with computer software, operated by an exchange member, which checks basic non-arbitrage restrictions[1] [2]. Because of this double scrutiny, settlement prices are a good approximation for the middle point of the closing bid/ask spread of the trading session, and reflect prices at which options could have been actually traded.

The dataset is also filtered according to minimum volume traded, strike price convexity and minimum option premium. The analysis uses options that, for any given day, have been traded above an established minimum volume. Prices of lightly traded options contain little to no information as they do not come from an agreement between buyers and sellers that actively negotiate the fair market value of the asset. Similar filters are regularly applied in studies of options (e.g., Coval and Shumway 2001; Egelkraut 2004). There is no established criterion to set the minimum volume figure. This depends on the specific market being analyzed, and on the time period under study. A practical rule used here is to analyze how the results change as this minimum volume figure is varied.

Strike price convexity constitutes a basic non-arbitrage relationship. It says that options prices must be convex functions of their strike prices, K, and that the slope of these functions should be less than one in absolute value. In practice sometimes option settlement prices do violate non-arbitrage relationships due to institutional factors, human errors, etc. However, those prices do not come from a true negotiation process, and can be seen as outliers that can potentially bias the analysis, thus those observations are excluded. Similar filtering criteria has been used by Jackwerth (2000).

[1] Mr. Dean Payton (Vice-President for Investigations and Audits at the CBOT), personal communication, October, 2004.

[2] Dr. Paul Peterson, personal communication, October, 2004.

Options whose price is less than three times the minimum tick size are also excluded from the analysis[3]. Options with such low prices are usually very illiquid and their trading normally constitutes block trades to liquidate positions. Furthermore, these observations have the potential to heavily bias the computations toward extremely high returns. Bondarenko (2003) have also applied similar filtering to his dataset.

Forward options prices are computed to express them in equivalent time-value money compared to the underlying futures price. For this, spot put, $p^s(\cdot)$, and call, $c^s(\cdot)$, prices are converted to forward prices as $p(\cdot) = e^{r_f(T-t)/365}p^s(\cdot)$, where t is the date when the option is bought, T is the expiration date. Thus, the holding period is equal to $T - t$ and r_f is the risk-free interest rate. Call forward prices are computed in similar way.

2.1 Historical Returns

In this study, the EMH is checked using returns to two trading strategies. The EMH was proposed by Fama (1970), and is normally used to formally test market efficiency. Once returns to these strategies are computed, the test for the EMH can be implemented as

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

Equation (1) says that conditional on the information set Φ available at time t the expected profits of trading security j should be zero (Fama 1970). In this case, r_j are the returns to trading the j asset, where j can be a put or a call. Finally, Φ_t is the information set formed by historical prices.

The general trading strategy used will be to buy the option a given number of days prior to expiration and hold them until expiration. Then, at expiration, a new set of option contracts having the same amount of time left to expiration are purchased and

[3]The tick size for hog options is \$0.00025/lb. Thus, option whose price is lower than \$0.00075/lb are excluded.

held until they expire, and so on. Trading strategies with holding periods of one and four months will be tested.

These trading strategies involve taking long positions. For the case of put (call) options, long positions earn (lose) money when the underlying futures price decreases. On the contrary, long put (call) positions lose (make) money when the price of the underlying futures increases. Note that when long positions make money, short positions lose money. Therefore, determining that long positions consistently make money would indicate that short positions consistently lose money, and vice versa. This would indicate that the equality in (1) does not hold. Note that ignoring transaction costs, and being the settlement price at the middle point of the bid/ask spread, the profits of the buyer of the option are equal to the losses of the seller of the option and vice versa. In other words, the pay off functions for longs and shorts are reverse images of one another.

In general, the decision maker modeled in this paper can be any rational risk-averse profit maximizing investor. However, some strategies, in particular the four months holding period strategy, can represent more closely hedging strategies for livestock producers. These strategies will have a smaller number of observations, but they will provide an approximation to the economics of hedging schemes with longer horizons using the commodity options included here.

Potentially there exist an infinite number of trading strategies, and it is not possible to simulate them all. However, the strategies chosen here have several advantages and collectively allow testing different aspects of market efficiency. For instance, the one-month holding strategy maximizes the number of non-overlapping return observations. This strategy may seem appropriate for a short-term portfolio investor. The four-month holding strategies represent situations that can be used by livestock producers. Since these strategies only involve trading once, they minimize the effects of transaction costs and/or bid-ask spreads.

The returns to a put, $r_{p,K}$, and to a call, $r_{c,K}$, with strike price K can be computed

as

$$r_{p,K} = \frac{\max(K - v_T, 0)}{p_{K,t}} - 1 \tag{2}$$

$$r_{c,K} = \frac{\max(v_T - K, 0)}{c_{K,t}} - 1 \tag{3}$$

where $p_{K,t}$ and $c_{K,t}$ are respectively the price of the put and the call with strike price K at time t, v_T is the price of the underlying futures at expiration. Note that these returns are in excess of the risk-free rate since options and futures contract prices were converted into forward prices.

Transaction costs are an important determinant of net trading profits. Options market trading costs can be broadly divided into two categories, brokerage commissions and bid-ask spread. The latter is also referred to as execution costs, liquidity costs, or skid error[4]. Brokerage commissions are readily available from brokerage service providers; however data on bid-ask spread is not usually available and must be estimated. There exists a large body of literature analyzing the bid-ask spread in futures and in stock options markets. However, where are not aware of any scientific estimate of bid-ask spreads for commodity options markets. In this study, the approach used is to compute the trading returns excluding trading costs (brokerage fees and bid/ask spread) from the analysis. Then, if risk-adjusted profits are found, the level of transaction costs needed to eliminate those profits will be analyzed.

In order to compute descriptive statistics on the time-series of returns, options will be classified according to their level of moneyness at time t, $k = K/v_t$. The moneyness, or leverage, is a measure of the ability of the option to magnify gains and losses. Such ability varies directly with the k-ratio. Options with different moneyness level have different behavior. For instance, the sensitivity of the option price to changes in the price of the

[4]There also other costs such as clearing, exchange and floor brokerage fees, these however are very small totaling approximately \$2 per contract (Wang, Yau, and Baptiste 1997).

underlying futures, (the option's delta and gamma) and to changes in its volatility (the option's vega), change with the moneyness ratio (see Hull (1999), chapter 14). Thus not every option can be directly compared with any other. Classifying options into moneyness categories ensures valid comparisons. According to this, puts are classified as out-the-money (OTM) if $k < 1$, at-the-money (ATM) if $k = 1$ and in-the-money (ITM) if $k > 1$. Similarly, calls are out-the-money if $k > 1$, at-the-money if $k = 1$ and in-the-money (ITM) if $k < 1$. Jackwerth (2000) and Bondarenko (2003) have used similar classifications to study option returns.

Practically these definitions say that OTM options have no value if they are exercised immediately. For instance, for an out-the-money put $max(K - v_T, 0) = 0$ when $K < v_T$. Conversely, ITM puts have some positive value if exercised immediately, since $K > v_T$, and thus $max(K - v_T, 0) > 0$. Finally, ATM puts are the ones where $K = v_T$. The opposite is true for call options.

Five moneyness categories will be defined, $k = 0.94,\ 0.97,\ 1.00,\ 1.03,\ 1.06$. Extending these categories further down or further up would include in the analysis options with non-desirable characteristics as explained above (*i.e.*, illiquid options with potentially nonsynchronous prices). Return observations will be classified in one of the five moneyness categories as follows, return observations whose k is $0.925 \leq k < 0.955$ will be assigned to the 0.94 category, return observations whose k is $0.955 \leq k < 0.985$ will be assigned to the 0.97 category and so on. Therefore, each trading strategy will yield five different types of returns, one for each k-categories $\{r_{0.94}, \ldots, r_{1.06}\}$.

In order to test the statistical significance of average options returns, 95% confidence intervals for the mean will be constructed through the technique of bootstrapping. This technique is used to obtain a description of the sampling properties of empirical estimators using the sample data. Given a sample of reasonable size, n, and a consistent estimator, the asymptotic distribution of the estimator can be approximated by drawing m observations, with replacement, from the sample vector B times. Where m can be

smaller, equal or larger than n. Then, from each of the B samples the estimator is computed (Greene 1997). In this study, m observations are drawn from each return vector of size n, 2,000 times, being $m = n$. Then, the mean return is computed from each of the 2,000 bootstrapped return vectors and a 95% confidence interval for the mean is computed. Bootstrapped confidence intervals are not affected by asymmetries in the distribution of returns.

2.2 Risk Adjustment

Computed returns need to be adjusted for risk, given that probably they are consistent with some theoretical model of returns and risks. For instance, say that put returns are negative on average. Then risk adjustments will 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[5].

In this paper, two basic methods to adjust returns for risk will be 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 $E\left[r_j\right]$ is the expected asset return and $Std\left[\cdot\right]$ 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

[5]Actually, this last possibility is predicted under the normal backwardation theory proposed by Keynes. However, the predictions of the theory are in qualitative terms, but not how much is a normal risk-premium.

more than the numerator yielding a low ratio despite the fact that those upside variations may be attractive to the investor (Bernardo and Ledoit 2000; 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 basically 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 rewritten 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. 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 (Black, Jensen, and Scholes 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). Despite the controversy described, CAPM will be used here to determine whether put returns are consistent with the theory underlying this model. Also, its inclusion here will allow comparing results with those of other studies.

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, Rausser, and Schmitz (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, Rausser, and Schmitz (1983) have 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 will be used as proxy for the market return in the CAPM. 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, such as a farmer. 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.

In order to test the observed returns against CAPM, the Jensen's alpha will be 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.*, it can be defined as $r_j \equiv r_{p,K}$ or $r_j \equiv r_{c,K}$). This is a risk-adjusted measure of the returns that the asset is earning above (or below) the returns predicted by CAPM — the excess return. Therefore, if observed returns are consistent with CAPM, the average α should not be different from zero. To test this hypothesis the modified t test proposed by Johnson (1978) will be used. This modified test allows for the possibility that the excess returns α_i are drawn from an asymmetric distribution[6]. If returns come from a symmetric distribution with zero skewness (*i.e.*, $U = 0$) the statistic collapses to the usual t-statistic. The Johnson's test statistic is

$$t_J = \frac{\overline{\alpha} + \frac{U}{6\sigma^2 n} + \overline{\alpha}^2 \frac{U}{3\sigma^4}}{\sqrt{\frac{\sigma^2}{n}}} \quad \longrightarrow \quad t_{n-1} \tag{7}$$

where $\overline{\alpha}$ is the mean, σ is the standard deviation, U is the skewness of the distribution of α_i and t_{n-1} is a Student t distribution with $n-1$ degrees of freedom.

The trading strategy with four-month holding period will produce overlapping re-

[6]This test has been used in similar studies of options returns (Bollen and Whaley 2004).

turns. It is well know that overlapping can bias statistical inference because returns are not independent, rather the time series is autocorrelated. When returns are correlated, the OLS estimator is still unbiased, but it is inefficient. In order to correct the standard errors of the t-statistics computed from the overlapping returns, the Newey-West autocorrelation consistent covariance estimator will be used. This procedure corrects for a general structure of autocorrelation yielding standard errors that are more efficient than the ones obtained from the traditional variance-covariance matrix. The Newey-West estimator is widely used to correct for non-spherical disturbances, and is described in Greene (1997).

2.3 Live/Lean Hogs Period Comparison

In order to study the effect of the hog options contract re-design the analysis will be done separately for the live hog contract period (1985–1996) and for the lean hog contract period (1997–2005). While the number of observations within each subperiod will be smaller, this analysis will help assessing the effect of contract re-design and change in settlement procedure on the efficiency level of this market.

3 Results

This section presents historic returns to buying and holding hog options during two different holding periods. 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, prices were more volatile during the lean hogs than during the live hogs period. In annualized terms, the average realized volatility of the futures price was of 20% during 1985–1996, and of 27% during 1997–2005. A rapid expansion of hog raising facilities caused major drops in futures prices particularly in December 1998, and in September 2002. Average trading volume is shown in table

1. Trading volume increases as expiration approaches. In general, trading is slightly heavier for OTM puts than for OTM calls. This suggest a demand for OTM puts to hedge hog inventories against market declines (Bondarenko 2003).

3.1 Options Returns

Table 1 shows several statistics of the historic returns for hog options with different k-categories. These returns are obtained including in the analysis options with a minimum daily trading volume of one contract. The same qualitative results can be obtained by setting the minimum volume equal to ten[7]. According to this, a minimum volume of one contract is considered to ensure a price that is informative of the option market value, while maximizing the number of observations.

Table 1 indicates that an investor buying and holding a hog call with $k = 0.94$ for 30 days would have gained on average 13.82¢ on the dollar. Similarly, an investor would have lost on average 28.43¢ on the dollar when buying and holding ITM puts with $k = 1.06$ for 120 days (table 1). Some of the returns in table 1 appear fairly large in absolute value, which would suggest option mispricing. For instance, the expected return for calls with a 120-day holding period and $k = 0.97$ is 33.2%. However, all confidence intervals for the mean return across moneyness and holding periods included zero in them (table 1). This indicates that investors can not rule out, with 95% confidence, a zero return when trading these options. In other words, it is not possible to rule out that the true mean of the return distribution is zero for most of the options.

These results suggest that investors would not be able to consistently make profits by taking either side of the hog option market. Sharpe ratio and CAPM were computed for option returns described in this section. The two risk-adjusted measures consistently indicate that hog options do not yield excess returns given their risk levels. This is expected, since the mean returns are not different from zero these assets do not consti-

[7]Results not presented, but available upon request.

tute attractive investments regardless of their risk levels. It is worth noting that these conclusions can not be changed by the inclusion of transaction costs or bid-ask spreads. This is because options are assumed to be traded only once, at the beginning of each holding period. At the end of which, options either expire worthless or are exercised with a small commission for the exercise. Returns would be driven closer to zero by introducing transaction costs and/or bid-ask spread, supporting even more the efficiency the hog options market.

Observed historical returns are highly variable in nature. Figure 2 presents the returns for ATM puts with 30 day holding period through time, and figure 3 shows the histogram of those returns. The holder of a put losses the premium most of the time, but obtains large positive returns on occasions. The ATM put expires worthless on 59% of the times (figure 3).

To better assess the economic significance of the results presented, the average dollar returns on a per contract basis are presented in table 2. Extreme per contract returns occur for the 120 day holding horizon for ITM options (*i.e.*, \$280 for calls and −\$238 for puts). Almost all dollar returns per contract are small enough in absolute value to have economic significance. Any potential profit from these returns would be greatly reduced or eliminated by the introduction of transaction and execution costs faced by market participants that trade through commercial brokers. For instance, assume that a typical bid/ask spread for hog options is 2 ticks/contract to open and 2 ticks/contract to close the position. Further assume a brokerage fee of \$50/contract, and a \$2/contract commission for exercising the option at expiration. According to this, it would cost \$72/contract to implement the strategies evaluated here. Since options are traded only once, half of the bid/ask spread is paid. Subtracting the 72 dollars transaction cost from the average returns in table 2, it can be seen that, aside for few cases, returns net of transaction costs are not economically significant.

The lean hog futures suffered a major drop in Dec 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 analisis the observations corresponding to the Dec–98 option contract. No significant difference were found in either historical returns, sharpe ratios or CAPM performance when results were re-calculated without the Dec–98 contract.

3.2 Live/Lean Hogs Period Comparison

Tables 3 and 4 present hog options returns, in percentage and in dollars per contract, for the live and lean hog periods, separately. Mean options returns differ substantially between the live and the lean hog contract periods. For instance, during 1985–1996, hog futures prices varied around a mean of \$64.3/cwt, but without significant spikes or trends in either direction. This caused expected call returns to be positive and expected put returns to be negative, in general. This situation is more evident for the 30-day holding period. On the contrary, the 1997–2005 period was characterized by significant drops in the hog futures price (figure 1), which caused average call returns to be negative and average put returns to be positive, in general. Again, this is more evident in the 30-day holding period (tables 3 and 4). For calls, five of the confidence intervals for the mean percentage returns, and four confidence intervals for average returns per contract do not include zero. For puts, three confidence intervals for the mean percentage return, and five confidence intervals for average returns per contract do not included zero[8]. Some of the returns per contract appear to be large enough to pay usual transaction costs and generate moderate profits. For instance, live hog calls appear to favor the buyer, while live hog puts seems to be profitable for the sellers. This would indicate that one side of the market can expect to obtain profits 95% of the times when trading these options

[8]Puts and calls dollar returns per contract are computed as $r_{p,K} * p_{K,t} * 40,000/112$ and $r_{c,K} * c_{K,t} * 40,000/112$, respectively. While these computations do not change the sign of the returns, they do change their magnitudes, as a consequence some confidence intervals may include zero when computed from percentage returns, but not when computed from dollar returns, or vice versa.

repeatedly. Despite this, it is necessary to adjust for risk these returns, because they might not be enough to compensate their level of variability. Larger absolute value per contract returns tend to occur during the live hog contract period. This would suggest that the new contract improved the efficiency of the hog options market.

With the exception of puts with 120 day holding, absolute value Sharpe ratios tend to be larger for live hogs than for lean hogs. Some of these ratios suggest that hog options provide returns in excess of their level of risk. Sharpe ratios for live hog calls with 30 day holding period range from 0.265 to 0.505 (table 3). Sharpe ratios for live hog puts with 30 day holding period range from -0.290 to -0.862 (table 4). Ratios for puts are comparable to the ones found for overpriced puts on financial futures. Bondarenko (2003) found Sharpe ratios for S&P500 futures puts ranging from -0.18 to -3.93. The maximum absolute value SR's is 3.304, for calls with $k = 0.94$ (Panel B, table 3), however there are only four observations in this moneyness category. Such a low number of observations is likely to provide a inefficient indicator. With the exception of 120 day puts, CAPM performs better during the lean hog period. In general, excess returns, α's, are smaller in absolute value during 1997—2005 (table 3, and Panel A of table 4). Overall, CAPM seems to predict options returns well. Excess returns are statistically different from zero in only four of the forty cases[9].

As in the previous section, options returns for the lean hog contracts were recalculated removing observations for the Dec–1998 contract. Expected returns, Sharpe ratios and CAPM performance were almost identical to the results presented in tables 3 and 4. Therefore, the price movements occured in late 1998 do not seem to been driving the conclusions about the lean hog options returns.

Results of comparing live to lean hog options appear mixed. Some options have average percentage returns that are statistically different from zero. Some dollar per contract returns appear large enough to pay transaction costs, and Sharpe ratios are of consider-

[9]There would be five rejections to CAPM including puts with $k = 1.06$ and 120-day holding (table 4).

able magnitude. However, CAPM indicates that expected returns are, in general, well balanced with their levels of risk. Options returns are function of the underlying futures price. While during the sample period, the hog futures does not exhibit significant trends, it is possible that movements in future price drive option returns computed here. This can be controlled for by computing trading returns from riskless trading strategies. These strategies form hedged portfolios of options and futures and are rebalanced periodically to account for variations in the futures price. Riskless trading strategies are widely used in studies of options returns (e.g., Coval and Shumway 2001; Bollen and Whaley 2004). Further research will compute returns to riskless trading strategies to control for the effect of futures price movements. Finally, in analyzing the two hog contracts separately, the number of observations is greatly reduced. Consequently, the power of the statistical tests used here decreases as well. This should be considered when interpreting these results.

4 Concluding Comments

This research has studied the efficiency of the hog options market by directly computing returns to low cost trading strategies. Returns have been adjusted for risk using the Sharpe ratio and the CAPM. This research is unique in studying the hog options market under two different settlement procedures. When considering the sample period as a whole, results indicate that no profits can be made by taking either side of the hog options markets. However, analyzing the live and the lean hog contracts separately, results appear mixed. Some evidence suggest that opportunities for speculative profits existed during the live hog contract period. If this evidence is confirmed, this would mean that the contract redesign improved the efficiency of the hog options market. These conclusions are not driven by the extreme price movements in the futures price occurred during late 1998. Further research should investigate whether general futures

price movements are responsible for these large returns.

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Table 1: Descriptive statistics for hog options returns across five moneyness categories and with 30 and 120 day holding periods.

	Calls					Puts				
k	0.94	0.97	1	1.03	1.06	0.94	0.97	1.00	1.03	1.06
Panel A: 30 days holding period										
Mean Return	13.82	3.63	20.79	15.48	16.94	42.10	7.24	15.79	4.21	-18.27
Std Dev	90.32	104.65	159.30	218.44	313.14	682.15	301.46	224.53	142.34	90.453
Skewness	0.852	0.805	1.283	2.162	3.392	6.684	4.947	3.558	2.071	1.571
Avg Vol	20	24	32	33	32	28	40	30	24	16
n	55	80	147	157	130	136	135	141	79	60
Panel B: 120 days holding period										
Mean Return	7.66	33.20	4.78	16.52	31.94	12.33	5.25	-9.67	-5.69	-28.43
Std Dev	61.86	130.41	158.57	188.88	226.67	256.19	207.87	165.33	158.88	134.32
Skewness	-0.403	0.734	1.640	1.953	1.646	2.672	2.491	1.943	2.017	1.873
Avg Vol	7	7	10	15	17	24	16	13	5	7
n	16	47	67	89	80	93	93	54	37	10

Returns are in percentage and over each respective holding period — not annualized; $k = K/v_t$; n is the number of observations. Bootstrapped 95% confidence intervals for the mean were constructed with 2,000 repetitions. All confidence intervals across moneynes categories and holding periods included the zero return.

Table 2: Average returns, in dollars per contract, for hog options across five moneyness categories with 30 and 120 day holding periods.

Holding	Calls					Puts				
Period	0.94	0.97	1.00	1.03	1.06	0.94	0.97	1.00	1.03	1.06
30 days	133	-9	80	46	5	-7	-23	27	31	-222
120 days	185	280	-29	37	46	19	63	-70	-38	-238

Put and call dollar returns per contract are computed as $r_{p,K} * p_{K,t} * 40,000/112$ and $r_{c,K} * c_{K,t} * 40,000/112$, respectively, where $r_{p,K}$ and $r_{c,K}$ are as in (2) and (3).

Table 3: Mean returns in percentage and in dollars per contract, Sharpe ratio, excess return, t-statistics and number of observations for call options during the live hogs and the lean hogs time periods across moneyness categories and holding periods.

	Period: 1985 - 1996					Period: 1997 - 2005				
	0.94	0.97	1.00	1.03	1.06	0.94	0.97	1.00	1.03	1.06
Panel A: 30 day holding period										
Mean (%)	38.56†	43.34†	62.95†	49.51	94.22	-3.96	-18.95	-2.98	-0.88	-26.83
Mean ($/contract)	444†	311†	262†	137	73	-91	-192	-23	2	-34
Sharpe Ratio	0.505	0.449	0.411	0.307	0.265	-0.041	-0.118	-0.064	-0.033	-0.064
α	37.05*	21.81	62.78*	53.70	81.42	-2.88	-18.50	-0.26	2.46	-26.55
t_J stat.	2.267	1.143	2.864	1.717	1.421	-0.118	-1.183	-0.008	0.123	-0.958
n	23	29	53	51	47	32	51	94	106	83
Panel B: 120 day holding period										
Mean (%)	-10.02	53.01†	45.26	43.97	82.39	60.70†	8.68	-26.11	-9.15	0.02
Mean ($/contract)	-161	467	314	196	259	1223†	50	-290	-112	-89
Sharpe Ratio	-0.163	0.289	0.255	0.227	0.255	3.304	0.160	-0.037	-0.049	-0.029
α	-14.06	41.86	42.75	39.65	85.97	66.20*	14.67	-21.47	-8.01	1.67
t_{NW} stat.	-0.919	1.382	1.161	1.067	1.644	7.141	0.503	-1.000	-0.323	0.055
n	12	26	29	43	31	4	21	38	46	49

Bootstrapped 95% confidence intervals for the mean were constructed with 2,000 repetitions. † Indicates that the confidence interval does not include the zero return. In CAPM, CRB index is used as r_m. α is the average excess returns, which is computed as $\alpha_{i,j} = r_{i,j} - E\left[r_j^{CAPM}\right]$ where $r_{i,j}$ is the ith return for the jth option and $E\left[r_j^{CAPM}\right]$ is as defined in (5). Asterisks (*) indicate significance at 5% level. t_J and t_{NW} refers respectively to the modified t-statistic (Johnson 1978) and to the t-statistic computed with standard errors corrected for autocorrelation through the Newey-West procedure. Both statistics test the null hypothesis $H_0 : \alpha = 0$.

Table 4: Mean returns in percentage and in dollars per contract, Sharpe ratio, excess return, t-statistics and number of observations for put options during the live hogs and the lean hogs time periods across moneyness categories and holding periods.

	Period: 1985 - 1996					Period: 1997 - 2005				
	0.94	0.97	1.00	1.03	1.06	0.94	0.97	1.00	1.03	1.06
Panel A: 30 day holding period										
Mean (%)	$-84.45^{\dagger}$	-41.49	-34.54	-25.16	$-34.66^{\dagger}$	102.62	30.01	41.76	27.58	-3.92
Mean ($/contract)	$-99^{\dagger}$	$-120^{\dagger}$	$-173^{\dagger}$	-154	$-356^{\dagger}$	37	23	131	179	-106
Sharpe Ratio	-0.862	-0.301	-0.293	-0.290	-0.302	0.125	0.120	0.123	0.125	0.123
α	-80.97*	-44.13	-33.77	-26.65	-41.99	100.49	34.39	41.63	23.89	-3.60
t_J stat.	4.955	-1.263	-1.594	-1.458	-1.549	1.174	1.001	1.580	0.965	-0.153
n	44	43	48	35	28	92	92	93	44	32
Panel B: 120 day holding period										
Mean (%)	-7.28	-32.86	11.91	-26.29	-10.85	29.19	44.20	-24.50	32.34	$-98.76^{\dagger}$
Mean ($/contract)	-20	-133	190	-256	122	53	263	-250	364	$-1681^{\dagger}$
Sharpe Ratio	-0.030	-0.082	-0.035	-0.054	-0.057	0.110	0.144	0.108	0.120	0.119
α	2.27	-31.68	13.38	-19.37	-20.25	26.73	50.58	-20.03	37.50	-96.33
t_{NW} stat.	0.051	-1.257	0.243	-0.659	-0.444	0.624	1.286	-0.857	0.632	‡
n	43	47	22	24	8	50	46	32	13	2

Bootstrapped 95% confidence intervals for the mean were constructed with 2,000 repetitions. † Indicates that the confidence interval does not include the zero return. In CAPM, CRB index is used as r_m. α is the average excess returns, which is computed as $\alpha_{i,j} = r_{i,j} - E\left[r_j^{CAPM}\right]$ where $r_{i,j}$ is the ith return for the jth option and $E\left[r_j^{CAPM}\right]$ is as defined in (5). Asterisks (*) indicate significance at 5% level. t_J and t_{NW} refers respectively to the modified t-statistic (Johnson 1978) and to the t-statistic computed with standard errors corrected for autocorrelation through the Newey-West procedure. Both statistics test the null hypothesis $H_0 : \alpha = 0$. ‡ for this case the small number of observations did not allow to compute the Newey-West standard error.

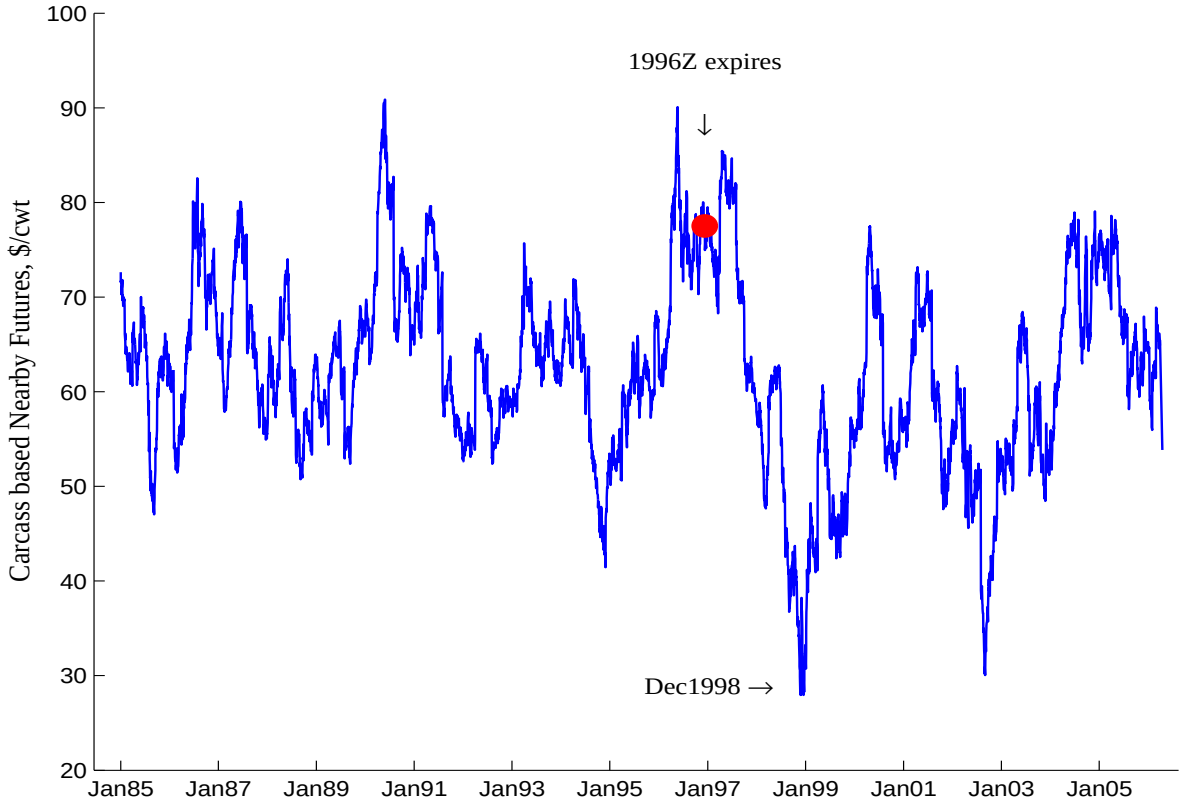

Figure 1: Carcass based nearby hog futures ($/cwt.) from Jan–1985 to Apr–2006. The dot indicates the expiration of the last live hog option contract, in Dec–1996.

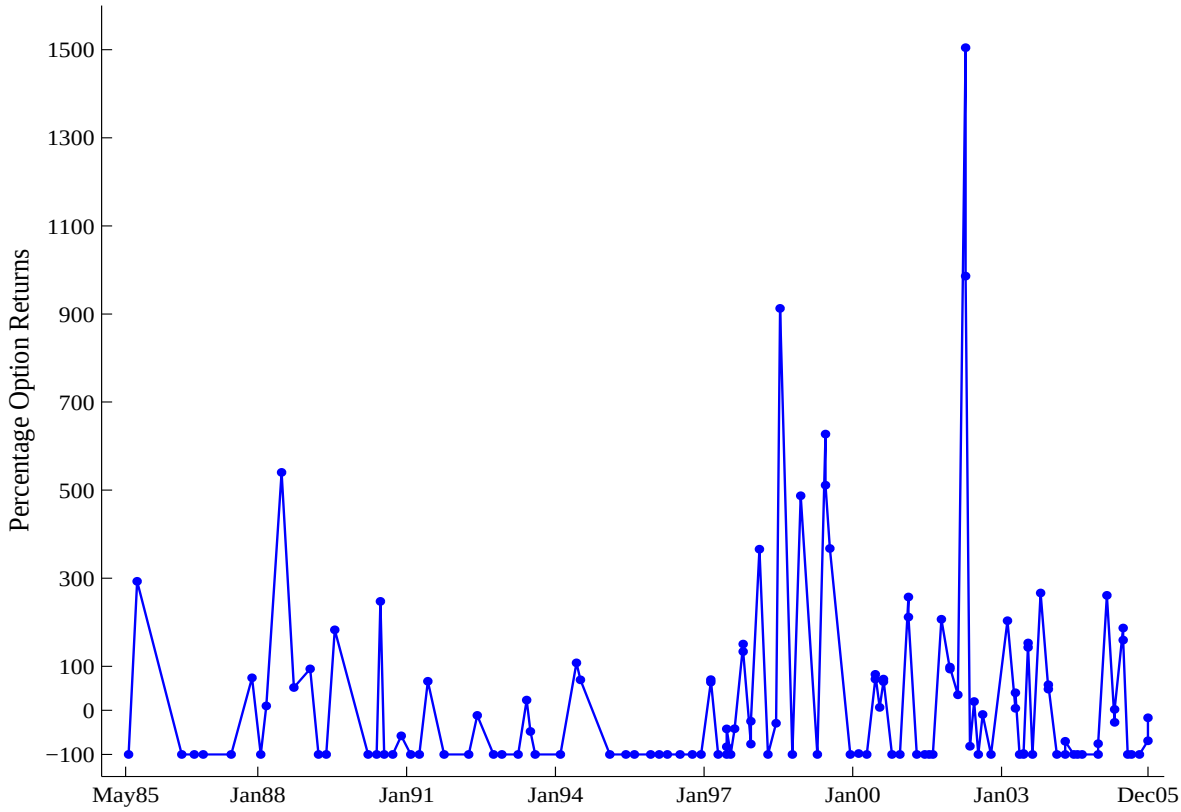

Figure 2: Options returns for ATM puts with 30 day holding period from May–1985 to Dec–2005. Number of observations, 141.

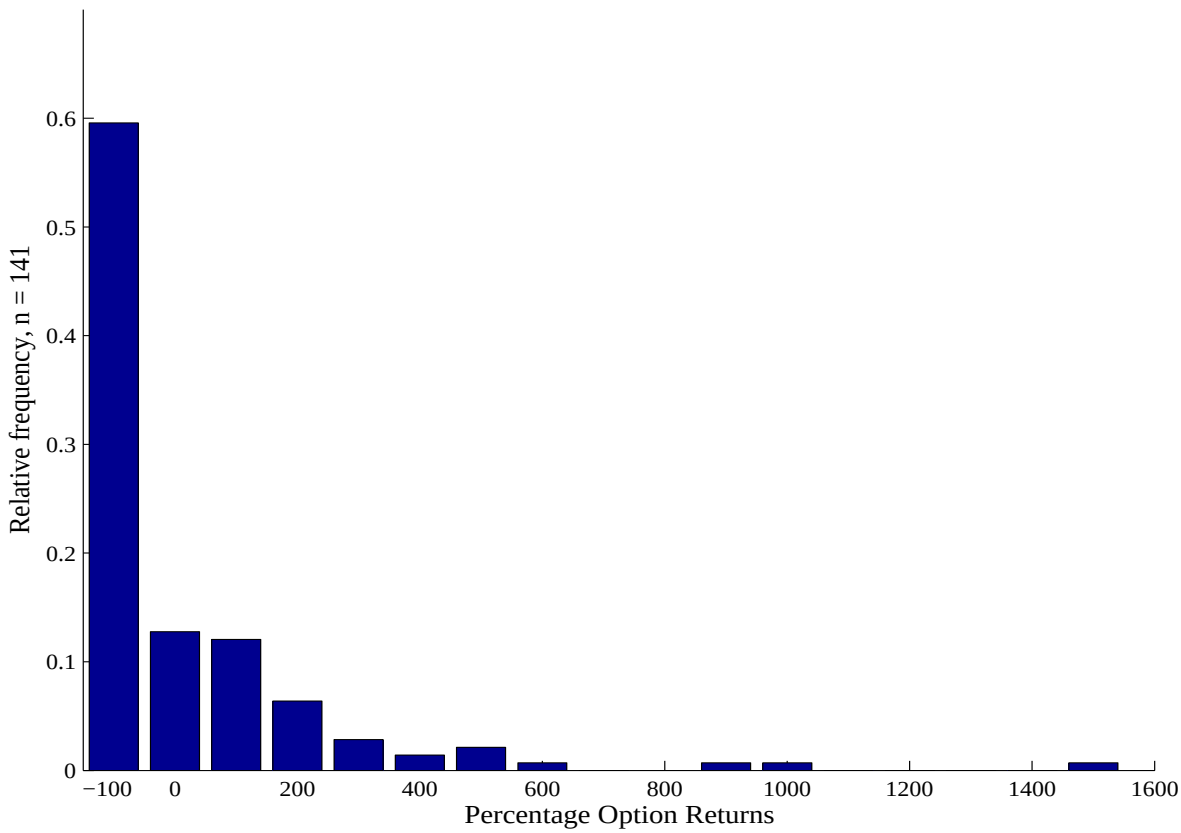

Figure 3: Histogram of returns for ATM puts with 30 day holding period from May–1985 to Dec–2005. Number of observations, 141.