Is there a “Right” Time to Buy Options Pre-Harvest?

by

Charles E. Curtis, Jr.
Olga Isengildina-Massa
and
Andrew Hummel

Selected paper presented at the
2007 Southern Agricultural Economics Association Meetings
Mobile, AL, February 2007

Abstract

This study analyses the variables that affect the option premium levels in an attempt to identify a period in time that would be considered "preferred" for the purchase of a December put option contract for corn and cotton. The daily futures and options data from January 1990 to October 2005 revealed that average prices of December cotton and corn futures tended to be higher in the month of March. The early months of the year also demonstrated low implied volatility levels while offering larger time to maturity. The analysis suggests that March may be a preferred time to purchase December cotton and corn put options.

Introduction

United States agricultural producers are competing in an increasingly global market and as competition increases domestic profit margins have become more volatile. Prices received for agricultural commodities are unstable due to the inherent nature of producing a biological product. Weather, pestilence and consumer demand are constantly fluctuating variables that a producer has little control over, yet these variables dictate the price the producer will receive when they sell their product.

In the early 1980's the Chicago Board of Trade and the New York Board of Trade introduced the use of options on agricultural futures. Options that give a purchaser a right, but not an obligation, to a long futures position at a specified price are known as "call" options, whereas options that give a purchaser a right, but not an obligation, to short a futures contract at a specified price are known as "put" options. This paper evaluates the use of options contracts by cotton producers. Therefore, the use of a put option as a market risk management tool will be examined.

The put option is a unique marketing tool that offers the purchaser the ability to set a price floor while allowing for gain from any potential upward movements in price. Therefore, the put option acts as an insurance policy for the purchaser against downward movements in futures price since a minimum selling price can be set. It is noted that basis risk remains with this strategy.

The purpose of this study is to analyze the variables that affect the option premium levels in an attempt to identify a period in time that would be considered "preferred" for the purchase of a December option contract for cotton. A preferred time for the option purchase can be a defined as a time when the option offers a large amount of insurance value for a relatively small premium.

Data

This study analyzed 16 years of data (Nian 2006) from January 1990 to October 2005. December cotton and corn option contracts were analyzed on a yearly basis from January to October of the expiration year. On each trading day daily settlement quotes were used to record the following information: the December futures contract price, the closest-to-the-money strike price, the put option premium, and the time remaining to option contract expiration. The final data set had 3,345 daily observations for corn and 3,103 for cotton.

Figure 1 (Figure 3 for corn) displays the monthly means of December futures prices over the 16 year period. The futures price for cotton and corn displays seasonality with March having the highest futures price. The cotton futures price increased from January to March, peaked in March and continuously decreased through August. The price increased from August to September and decreased in October. This observation suggests that March may be an opportune time for cotton and corn producers to set the price floor.

Figure 2 (Figure 4 for corn) displays the standard deviation from the mean for December cotton futures. This figure shows that from January to June the level of standard deviation in prices increased. The level dropped slightly from June to July and increased from July to the highest level in October. The months of January, February and March have the lowest levels of standard deviation. The combination of the high average price levels with low standard deviations highlights March as an attractive month for setting the price floor. However, it is important to keep in mind that premiums must be paid in order to purchase options. The amount of the premium will determine the effective price floor that is set. Therefore, the next section explores factors that affect option premiums.

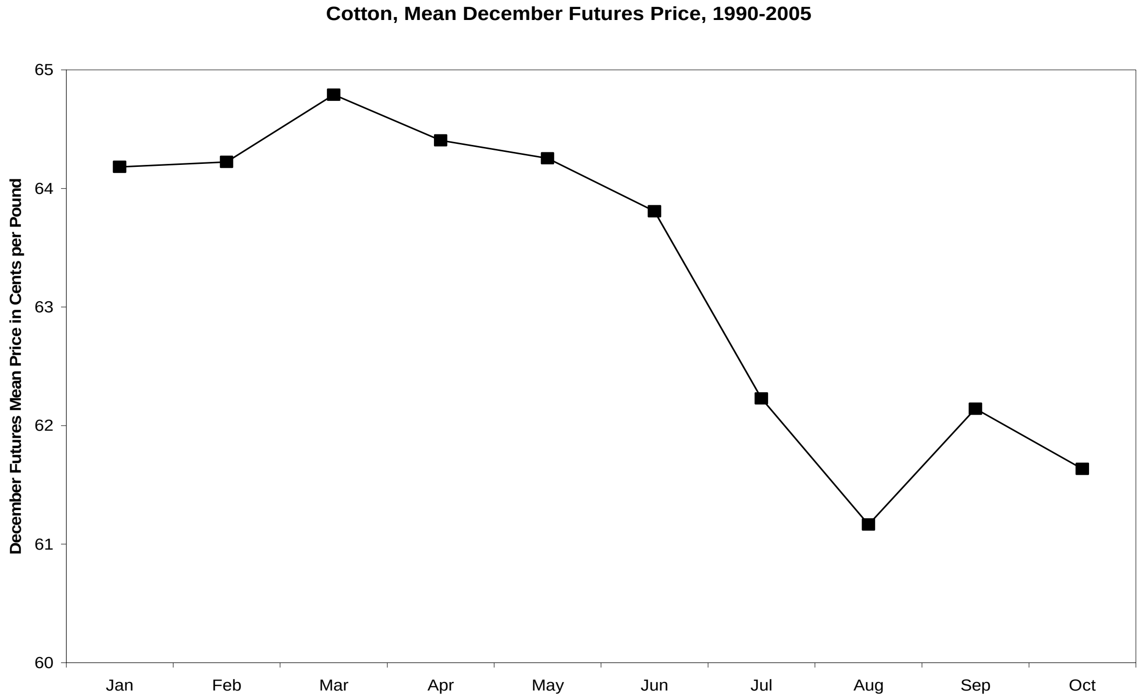

Figure 1. Mean Price of December Cotton Futures, 1990-2005.

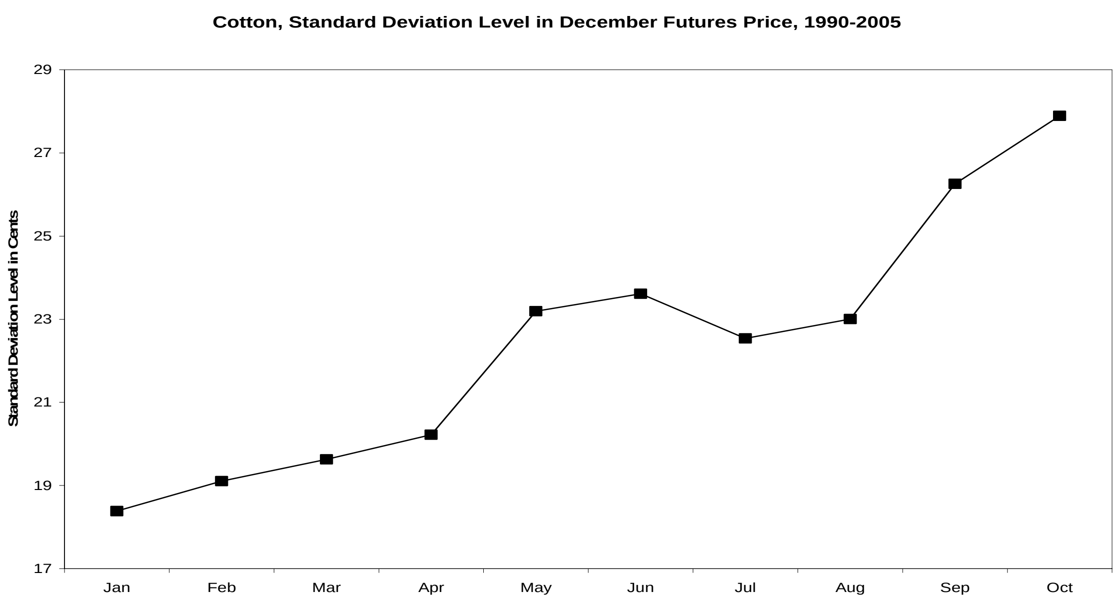

Figure 2. Standard deviation level in December cotton futures prices, 1990-2005.

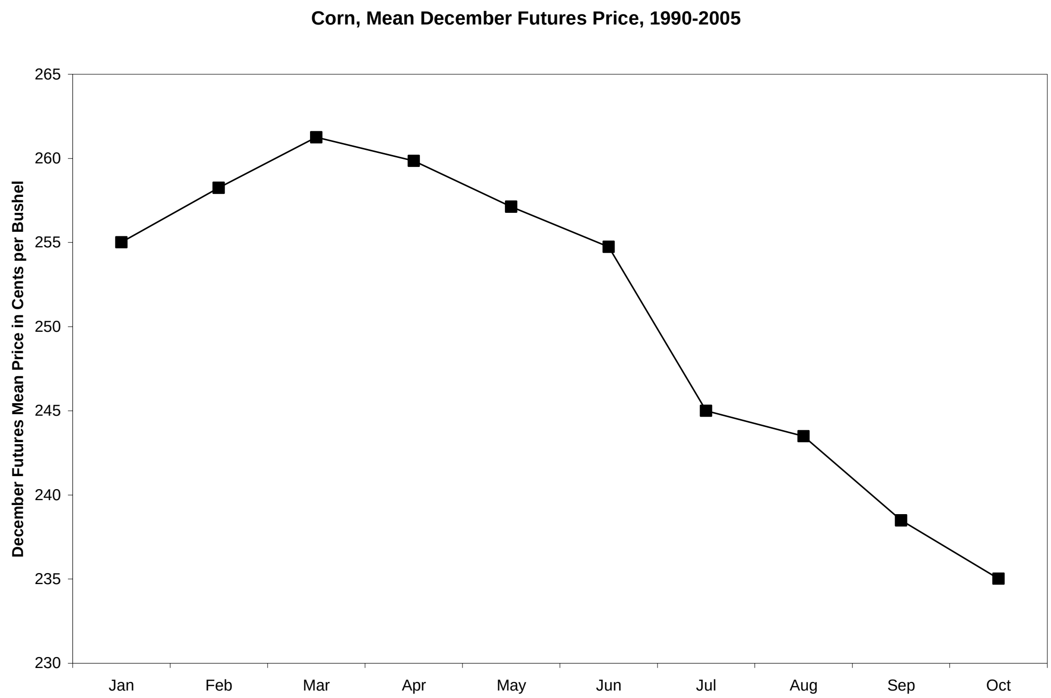

Figure 3. Mean Price of December Corn Futures, 1990-2005.

Figure 4. Standard deviation level in corn December futures prices, 1990-2005.

Factors Affecting Option Premiums

The Black-Scholes (1973) model is the benchmark model used to evaluate option premiums (Hull 2006). This model states that the option premium is a function of the following variables: futures price, strike price, interest rate, time to contract expiration, standard deviation of underlying futures price and the standard normal cumulative distribution function. The Black-Scholes model was developed for European options, which can not be exercised until contract expiration. American options can be exercised before contract expiration, and if the options do not pay a dividend, the European model and American model can be assumed equal.

The formulae for the Black-Scholes model are as follows:

$$c = e^{-rt}[f\Phi(d_1) - x\Phi(d_2)]$$

$$p = e^{-rt}[x\Phi(-d_2) - f\Phi(-d_1)]$$

Where:

$$d_1 = \frac{\ln(f/x) + (\sigma^2/2)t}{\sigma\sqrt{t}}$$

$$d_2 = d_1 - \sigma\sqrt{t}$$

ln = the natural logarithm, and:

c = the call option premium

p = the put option premium

f = the current underlying futures price

x = the nearest-to-the-money strike price

r = the continuously compounded risk free interest rate

t = the time in years until the expiration of the option

σ = the standard deviation of the underlying futures price

Φ = the standard normal cumulative distribution function

Futures and Strike Price

The *f* in Black-Scholes equation is the current futures price for a given commodity which underlies an option. The *x* in the equation is the strike price specified in the option contract. Strike prices are offered at various levels and a put option may be purchased with a strike price that is above or below the current futures price. A put option strike price that is above the current futures price is referred to as "in-the-money" because the option contract would have more value than the futures contract if the option were exercised immediately. Therefore, a higher premium must be paid for increasing levels of in-the-money strike prices since the put option becomes more valuable as the in-the-money strike price increases.

A put strike price that is below the futures price is referred to as "out-of-the-money" because the option contract would have less value than the current futures contract if the option were exercised immediately. As the level of the out-of-the-money strike price decreases the premium associated with that contract decreases, because the put option contract becomes less and less valuable.

This study examined the nearest-to-the-money strike price since the majority of trading volume occurs at strike prices nearest-to-the money. The high volume of trading data allows the assumption that the data is more reliable than data from strike prices that are further from the money and less traded (Nian 2006).

Interest Rate

The *r* in the equation is the risk free interest rate. The prime interest rate was used as the approximation for the risk free interest rate for this study. There is an inverse relationship between the put option premium and the risk free interest rate. The inverse relationship is due to the opportunity cost effect. The seller of the option is able to invest the premium at the current interest rate. If the interest rate is high, the option seller will receive a high rate of return from the premium received upfront. Therefore, with all other variables used to price an option held constant, at a higher interest rates, a higher rate of return will be received from the option premium, so a lower premium will be charged for the option (Purcell, Koontz 1999).

Time Remaining Until Option Contract Expiration

The t in the equation refers to time reaming until option contract expiration and is measured as a percent of a year. The more time remaining until contract expiration the more opportunity there is for downward movements in price. In order to buy protection against the downward price movements, an option contract with a large amount of time remaining will require, with all other variables held constant, a higher premium than an option contract with a small amount of time remaining. The higher premium is required for an increased amount of protection against the risk associated with time.

If all other variables are held constant the effect time has on the predicted premium can be graphically displayed. Figure 3 shows the level of predicted premium for a corn option as a function of time. This premium level was computed by holding futures price, strike price, interest rate and implied volatility constant over the 1 year time period prior to options contract expiration. The x-axis of the graph shows the percent of a year remaining until contract expiration; the y-axis displays the predicted premium level. There is a positive quadratic relationship between time to maturity and predicted premium. As time decreases the time insurance benefits the options offers become less and less valuable. Therefore, as shown on Figure 3, as time to maturity decreases the predicted premium decreases at an increasing rate.

Implied volatility

The σ in the Black-Scholes equation is the standard deviation of the underlying futures price of the commodity. The standard deviation can be interpreted as the volatility of the futures price around an expected value. According to Hull (2006), implied volatilities are the volatilities implied by the options prices observed in the market. For this study the standard deviation for the underlying futures price will be referred to as "implied volatility".

Implied volatility can be interpreted as a measure of uncertainty of the future value of a commodity. The put option contract can be viewed as an insurance policy that protects the producer from downswings in the price of the commodity associated with volatility. When volatility is high, the level of uncertainty of the future value of a commodity is high; therefore, the risk of a downturn in prices is increased. A put option purchaser at that moment will pay a higher premium in return for the increased level of protection associated with a high level of future uncertainty. On the other hand, if the implied volatility level is low, uncertainty is reduced and the option premium will be reduced to reflect the reduced level of uncertainly the option must protect against (Nian 2006).

Implied volatility cannot be directly observed in the market and must be solved for. Since *f, x, r, t* and *p* are observable; the estimated level of implied volatility is obtained by equating the theoretical option price to the observed option premium. Figure 4 displays the predicted premium for a corn option as a function of implied volatility. By holding futures, strike price, interest rate and time to maturity constant we can display the effect different levels of implied volatility have on predicted premium. The x-axis of Figure 4 displays levels of implied volatility from 0.6 to 0.0, while the y-axis displays the predicted premium for each level of implied volatility. It is shown that there is a positive linear relationship between predicted premium and implied volatility. As the level of implied volatility increases the predicted premium increases at a constant rate. Since implied volatility is a measure of uncertainty, a higher premium must be paid for protection against higher levels of uncertainty. Equally, when the level of implied volatility is low, a small amount of premium must be paid for protection against the smaller amount of uncertainty.

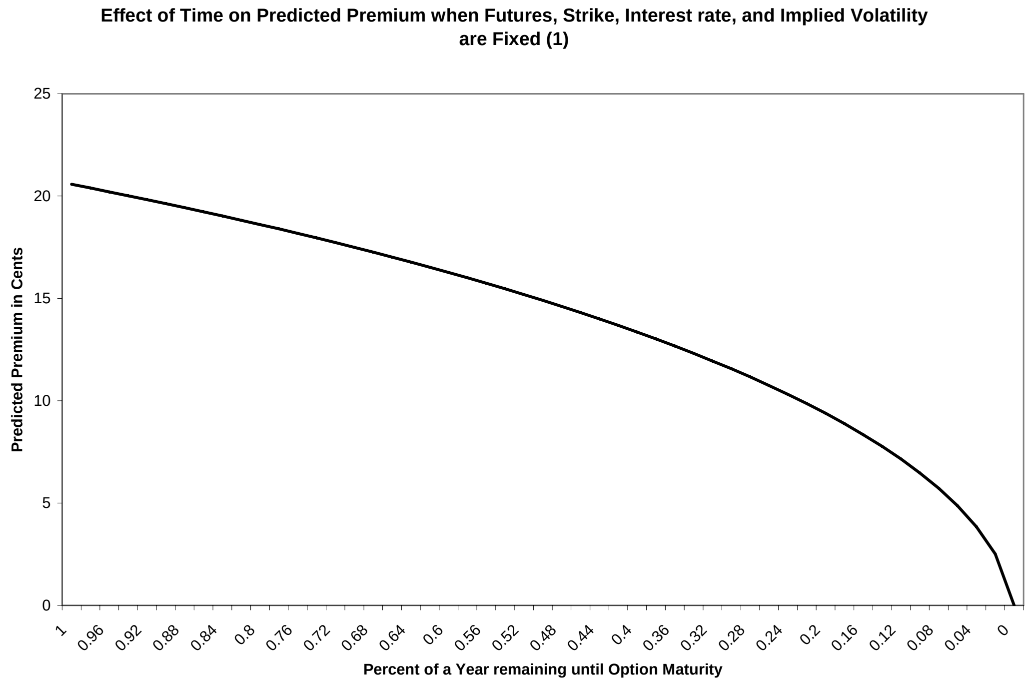

Figure 5. Effect of Time on Predicted Premium when Futures, Strike, Interest Rate, and Implied volatility are fixed. For this example the corn futures and strike price were fixed at $2.50, interest rate was fixed at 7.2%, and implied volatility was fixed at 23%.

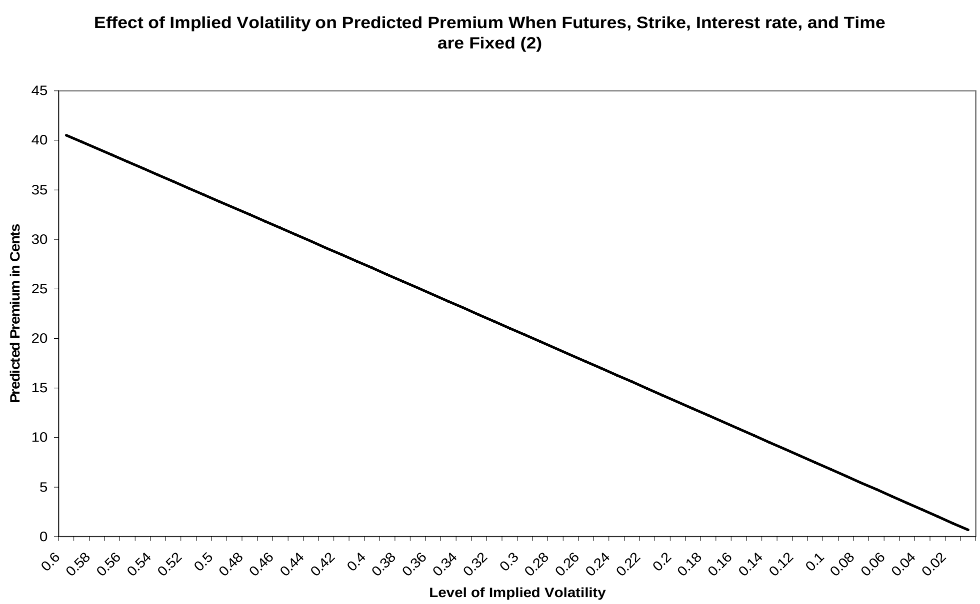

Figure 6. Effect of implied volatility on predicted premium when futures, strike, interest rate and time are fixed. For this example the corn futures and strike price were fixed at $2.50, interest rate was fixed at 7.2%, and time was fixed at 50% of a year.

Relative Impact of Time and Implied Volatility on December Option Premiums

Based on the Black-Scholes formula, implied volatility and time to maturity play a large role in determining the predicted premium. The previous section of the paper established that there is a positive linear theoretical relationship between predicted premium and implied volatility, and positive quadratic theoretical relationship between predicted premium and time to maturity. Using the observed data for cotton, regression analysis can be used to verify if the observed data reflects the theoretical conjectures. Regression analysis was used to form a model to predict the put option premium based on the independent variables implied volatility and time to option maturity. Additionally, regression analysis was used to explain how much variation in the predicted premium is accounted for by the two independent variables implied volatility and time to maturity. The prediction model used was:

$$p = \beta_0 + \beta_1\, iv + \beta_2\, tm + \varepsilon,$$

where p is the predicted put premium for the option, iv is implied volatility and tm is time to option maturity.

Table 1 displays the regression analysis results. The F-value for the model was 3189.06 with a p-value of <.0001 which allows us to conclude that at least one of the independent variables is useful in predicting the put option premium. The R^2 value infers that approximately 67 percent of the variation in predicted premium is explained by the independent variables. The p-values for implied volatility and time to maturity are both <.0001 which allows us to conclude that both variables are useful in predicting the put option premium.

The coefficients for implied volatility and time to maturity are both positive, so there is a positive relationship between implied volatility and predicted premium, and time to maturity and predicted premium. Again, the observed data supports the theoretical data put forth earlier in the paper. The implied volatility parameter estimate for cotton shows that for every one unit increase in implied volatility the predicted put option premium will increase by $0.0008. The time to maturity parameter estimate shows that for every one unit increase in the percent of a year remaining until maturity the predicated put option premium will increase by $0.0003.

Table 1. Coefficient Estimates of Implied Volatility and Time to Maturity on Predicted Put Premium for Cotton $N = 3103$

Variable	Coefficient	Std Error	t-Value	p-Value
Constant	0.02896	0.04864	0.60	0.5517
IMPLIED VOLATILITY	0.07649	0.00193	39.60	<.0001
TIME TO MATURITY	0.03292	0.00042906	76.73	<.0001
$R^2 = 0.6729$, MSE = 0.30185				

Table 1. Coefficient Estimates of Implied Volatility and Time to Maturity on Predicted Put Premium for Corn ($N = 3345$)

Variable	Coefficient	Std Error	t-Value	p-Value
Constant	-12.93429	0.25439	-50.84	<.0001
IMPLIED VOLATILITY	0.86777	0.01058	82.06	<.0001
TIME TO MATURITY	0.16749	0.00179	93.52	<.0001
$R^2 = 0.8444$, MSE = 6.07145				

The above models were also used to test the data for structural break. This test was conducted in order to insure that the patterns observed in the data were consistent throughout the entire study period. A conventional measure to determine structural changes in parameters is the Chow test. The Chow test splits the data into two subgroups, estimates the parameters for each group and checks for equality among the parameters of groups using an *F* statistic. A drawback of the Chow test is that it may overlook true breakpoints in the data because the breakpoints are dictated by the researcher. If the true breakpoints are not tested the parameters in the model may be assumed constant over the entire time period when in fact they are not.

In order to be able to determine the true breakpoints in the data, Quandt (1960) suggested taking the Chow values for all possible breakpoints. By testing all possible breakpoints we can have a higher level of confidence that we have not overlooked the true breakpoints and that the parameters are stationary. The largest Chow value observed is compared to a critical value composed by Andrews (1993) and Andrews and Ploberger (1994). If the largest Chow value observed does not exceed the critical value it can be concluded that there is no structural change in the data.

For this study a 15 percent trim was used on the tails of the data. The trim ensures that the subgroups of the data were not improperly balanced. Every break point for the central 70 percent of the data was tested to examine if there was a structural break in the model. The critical value at the 10% level of significance for the model was 5.00 (Stock and Watson, p. 471). The highest observed Chow statistic was 4.88 which allows us to conclude that there was no structural break in the data and the observed patterns are consistent across the entire study period.

Figure 5 displays the observed implied volatility level, shown as a solid line, and time remaining for cotton, shown as a dotted line. The levels of implied volatility are lowest in the earlier months of the year, plateau from June to September, and slightly drop off in October. Implied volatility is at the highest levels during the summer growing season. The plateau of high implied volatility in July though September is a reflection of the uncertainty of the future value of the cotton crop. During these summer months the cotton crop is exposed to the potential of drought, floods, and hurricanes that can destroy a crop. The high level of uncertainty is reflected by the high level of implied volatility. Once harvesting begins in late September and October the implied volatility level drops since the amount of time for weather damage to the crop is reduced.

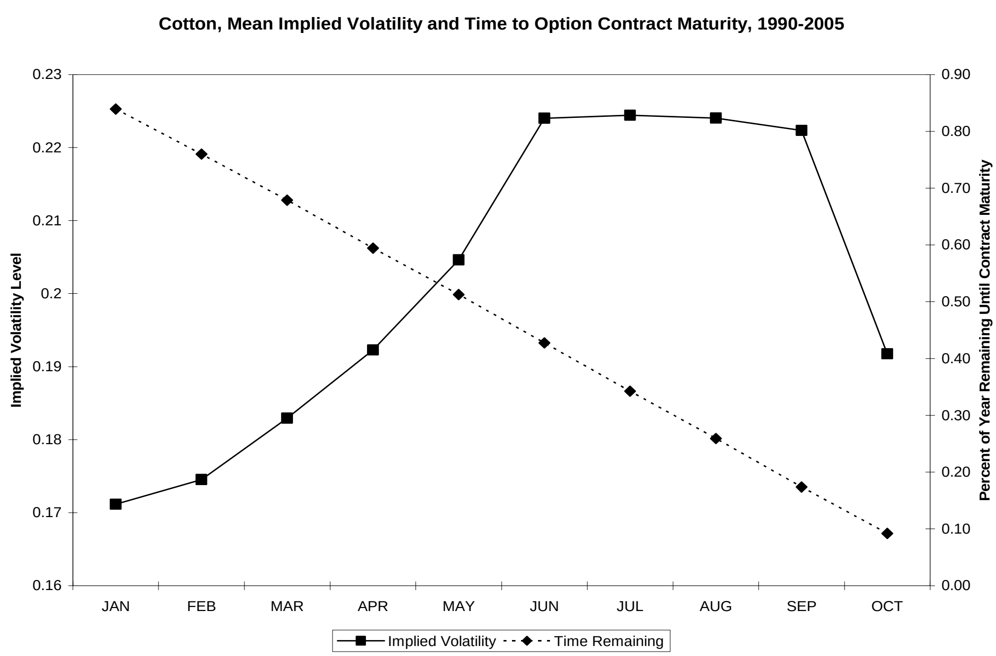

Figure 7. Cotton, monthly means of implied volatility and time to option contract maturity, 1990-2005.

Based on the observed data in this sample, January, February or March would be the preferred month to purchase a cotton option contract because implied volatility is low and time to maturity is large. The low premium associated with the low level of implied volatility will offset the high premium associated with the large amount of time reaming until contract expiration. Figures 1 and 2 showed that March also has the benefit of having the highest observed level of December futures prices combined with low standard deviation. When the insurance benefits of the December option are combined with the price benefits, March can be viewed as a preferred time to purchase an option contract.

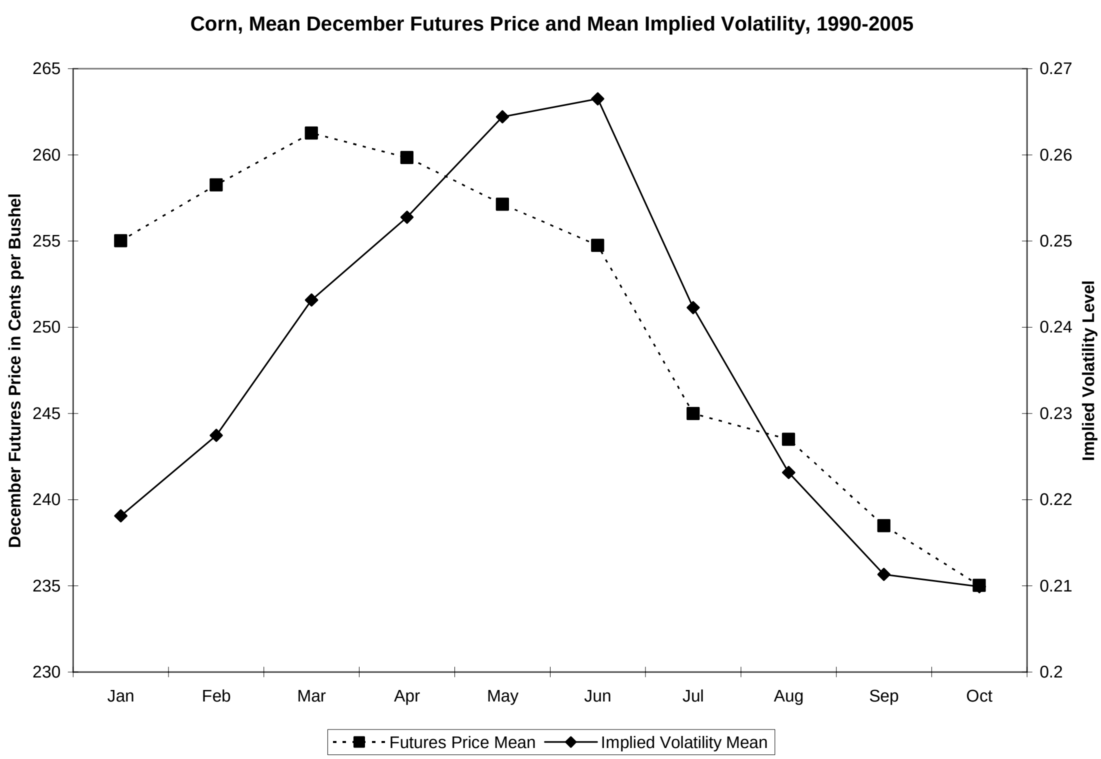

Figure 8. Corn, monthly means of implied volatility and time to option contract maturity, 1990-2005

SUMMARY AND CONCLUSIONS

The option is purchased as an insurance policy against the risks associated with time and uncertainty. When there is a large amount of time remaining until option maturity the opportunity for downturns in prices is high and a high premium must be paid for protection against negative price movements.

Likewise, when the level of uncertainty of the future value of a commodity, measured by implied volatility, is high, a high level of premium must be paid for protection against downswings in price. Based on the observed data, March displayed a large amount of time to maturity and a low amount of implied volatility. By purchasing a contract in March the purchaser is receiving a large amount of time insurance and must pay a high premium as a result. However, the relatively low level of implied volatility, which requires a lower premium, will offset the high premium associated with the large amount of time protection. The purchase of an options contact in March can be considered a bargain for the purchaser. They are able to purchase a large amount of time insurance, at a relatively low premium, due to the reduced implied volatility levels March offers.

The analysis of seasonality in December futures prices for corn and cotton concluded that seasonality is present and the highest level of futures prices occurred in March. For this study, the nearest-to-the-money strike price was used, which allows the assumption that the strike price and December futures value are approximately equal. This allows us to conclude that seasonality was present in the nearest-to-the-money December strike prices as well. Based on the observed seasonality of December strike prices, March would be the preferred month to purchase December put option contract.

In addition to March having the highest observed futures price, it was also shown the months of January, February and March had the lowest levels of standard deviation in futures prices compared to the later months. It is to the purchaser's advantage to purchase an option contract when price deviation is small. If the deviation in prices is high the producer may inadvertently purchase an option at a temporary low point in the futures price. Lower levels of price deviation give the producer more confidence that the strike price specified in the option contract will not jump up or down by large amounts in the near future.

When the high level of insurance protection March offers, at a reduced premium, is combined with the historically high strike price and low standard deviation level, March becomes the preferred month to purchase a December put option contract for cotton.

FUTURE RESEARCH

While this study outlines a preferred time to purchase cotton options pre-harvest, the next stage of the analysis would include the evaluation of alternative marketing strategies that rely on this timing. This analysis could be performed in optimization framework where the benefits from using options are reviewed for the various states of nature. Furthermore, yield variability and the impact of farm program participation on the revenue outcomes from alternative strategies will be considered.

REFERENCES

Andrews, Donald W.K. 1993. “Tests for Parameter Instability and Structural Change with Unknown Change Point.” *Econometrica*. July, 61:4, pp. 821-56.

Andrews, Donald W.K. and Werner Ploberger. 1994. “Optimal Tests When a Nuisance Parameter is Present Only Under the Alternative.” *Econometrica*. November, 62:6, pp 1383-414.

Black, F. and M. Scholes. “The Pricing of Options and Corporate Liabilities.” Journal of Political Economy, 81 (1973):637-59.

Hull, John C. 2006. *Options, Futures and Other Derivatives*. Sixth Edition. Prentice Hall, Upper Saddle River, NJ.

Koontz, Stephen R. Wayne D. Purcell. *Agricultural Futures and Options*. Second Edition. Prentice Hall, Upper Saddle River, NJ.

Nian, Minhuan. 2006. Unpublished PhD. Dissertation, Applied Economics and Statistics, Clemson University, (August, 2006).

Quandt, Richard. 1960. “Tests of the Hypothesis that a Linear Regression Obeys Two Separate Regimes.” *Journal of the American Statistical Association*. 55, pp. 324-30.

Stock, H.H., and M.W. Watson. 2003. *Introduction to Econometrics*. Pearson Education, Inc., New York.