PRICE VOLATILITY IN COTTON

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Abstract

Price volatility in the December contract of cotton was examined over the 1987-1997 period. An ARCH model was used to estimate the effects of seasonality, time-to-maturity, policy, weather, and supply and demand conditions on the variability of prices from planting to harvest. Findings indicate that there is a seasonal pattern to price volatility. Changes in farm policy do not appear to have had a significant impact, but the loan rate tends to have an inverse impact on volatility. Finally, there appears to be a non-linear relationship between the level of the futures price and price volatility.

Introduction

Changes in farm and international trade policy have increased attention to issues of risk management and price volatility. In relation to risk management strategies, there has been a variety of literature dealing with such issues as crop insurance (Knight and Coble, 1998) and forward pricing decisions (Feder, Just, and Schmitz, 1980). Models of forward pricing decisions (optimal hedge ratios) which include production risk (McKinnon, 1967; Grant, 1985) as well as models which include basis risk (Benniga, Eldo, and Zilcha, 1983; Heifner, 1973; Kahl, 1983) find that the optimal hedging level is conditional on price variability. These results, first found under the limiting assumptions of mean-variance analysis, have generally held in the less restrictive expected utility framework (Lapan and Moschini, 1994). Thus, the results available in the literature suggest that optimal hedge ratios are implicitly driven by the volatility of futures prices (Lence and Hayes, 1994). It has also been shown that options, which derive value from the volatility of the underlying futures price, can be part of the producer's optimal price risk management scheme (Sakong, Hayes, and Hallam, 1993; Moschini and Lapan, 1995). Given these findings, the volatility of futures prices is of importance to producers and other market participants.

There are many factors that are believed to affect the volatility of futures prices. Streeter and Tomek (1992) characterize variables in terms of information flow effects and market structure effects. Information flow effects relate to those factors which increase or decrease the amount of information in the marketplace. There are alternative avenues through which the information flow effects are expressed. Some authors examine the "time-to-maturity" effect (e.g., Hennesey and Wahl, 1996; Samuelson, 1965) by specifying a variable composed of the number of months (or days) to contract maturity. This is sometimes referred to as the "Samuelson hypothesis." The underlying premise of this hypothesis is that information about the crop will be more limited the more removed in time one is from contract maturity. As time progresses, more information comes into the market and prices become more volatile as market participants work out the proper impact of this information on future prices. Thus, volatility is expected to increase the closer to contract maturity. Previous work using this variable, however, has found that the "time-to-maturity" effect is limited when controlling for other variables such as seasonal effects on volatility (see, e.g., Hennesey and Wahl, 1996).

In addition to the "Samuelson hypothesis," the literature also points to the applicability of the "state variable hypothesis" (Stein, 1979; Anderson and Danthine, 1985). The premise of this hypothesis is that the variability in prices is some function of the variation of the underlying state variables. An original variable considered in this hypothesis was seasonal effects. In critical times of crop development, prices have typically been found to be more volatile because of the uncertainty about crop conditions. Market participants likely become acutely sensitive to new information during these times. A common method for examining seasonal effects is the use of seasonal dummy variables (e.g., Kenyon et al., 1987; Hennesey and Wahl, 1996). Streeter and Tomek (1992) and Goodwin and Schnepf (1998), in contrast, used a harmonic approach for addressing seasonality by adding a series of sine and cosine variables to a regression on price volatility. The appealing feature of this approach is that it allows for a continuous change and non-linearity in volatility with respect to seasonality versus the discrete changes forced by the use of dummy variables.

Literature also points to the importance of considering economic variables in addition to the information variables (Kenyon et al., 1987; Streeter and Tomek, 1992; Glauber and Heifner, 1986; Goodwin and Schnepf, 1998). For example, both Kenyon et al. (1987) and Glauber and Heifner (1986) found a direct relationship between the level of futures prices and price volatility. That is, as prices increased, price volatility also tended to increase. Price level, as Streeter and Tomek (1992) argue, may be reflecting the effects of supply and demand on price volatility. Thus, it may difficult to ascertain the effects of supply and demand variables when the price level is included in a model of volatility. One missing element from the literature is the potential for a non-linear relationship between price and volatility. There may be reason to believe that price influences volatility in a non-linear fashion, as is demonstrated in this paper.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:328-334 (1999)
National Cotton Council, Memphis TN

Other economic variables have also been found to be important to price volatility. For example, Goodwin and Schnepf (1998) found that variables such as private stocks, market concentration, and exports were significant determinants of price volatility in grains. In contrast to other studies, these authors found an important role for time-to-maturity in conditional heteroskedasticity models. Hennesey and Wahl (1996) found that the decision variable of planting time significantly impacted price volatility, likely through the introduction of new information into the market during planting time.

The available body of literature provides some indication of variables that may help explain volatility. Despite this accumulation of evidence in grains, little work has addressed price volatility in cotton. Understanding price volatility is important for several reasons. Early concerns were that the Federal Agricultural Improvement and Reform (FAIR) Act of 1996 would increase the volatility of commodity prices. Recent work by Ray et al. (1998) appears to confirm this concern in grains, but does not necessarily suggest this will happen in cotton. Others argue that increases in price volatility as a result of the FAIR Act may not necessarily occur (Collins and Glauber, 1998; Goodwin and Schnepf, 1998). Understanding what has affected volatility may give indications about what to expect in the future. Thus, the objective of this paper is to examine the determinants of price volatility in cotton, focusing on the growing season volatility of the harvest (December) contract.

Price Volatility

The growing season volatility of the harvest contract was selected for two primary reasons. First, information about the crop is limited prior to planting, thus limiting price volatility (assuming no shocks in demand). Confining the sample period from planting to harvest should eliminate most of the seasonal variation in volatility that is attributable to the pre-planting lack of market activity yet retain the seasonal variation that occurs within the growing season. Second, growing season volatility is of particular interest to cotton producers because many of their marketing decisions are usually made during this period. At the same time, the harvest contract is used by other market participants to begin pricing cotton for delivery to their mills or warehouses. Thus, this contract is of interest to the majority of market participants.

Growing season is defined for this analysis as the period between May 1 and the close of the December contract for each year. On average in the U.S., cotton planting is over half completed by the end of May and harvest is essentially complete by the close of the December contract (NASS, Various Issues). Thus, this seven month period should isolate volatility to that which occurs within the growing season.

Price volatility for this analysis is defined as the annualized standard deviation of daily price changes:

$$VOL_i = \sqrt{\frac{260}{n-1}\sum_{i=1}^{n}\left(\ln\left(\frac{P_t}{P_{t-1}}\right)\right)^2}$$

where VOL_i is the annualized volatility of cotton futures prices for month i, n is the number of trading days in each month and P_t is the futures price on day t (this formula was suggested by Hull (1997) and used by Heifner (1997); it differs from the approach followed by those such as Hennesey and Wahl (1996) who calculate annualized variances). Equation 1 generates an annualized volatility for each month (May, June, July, etc.) during the growing season. Multiplying equation 1 by 100% converts VOL_i into percentage terms so that it can be expressed as a percentage price volatility. A value of 260 days is chosen to approximate the number of trading days per year (Hull, 1997).

Table 1 shows the annualized volatilities in percentage terms for each month (growing season) from 1982 through 1997, as well as the average monthly volatilities over the study period (Figure 1 is a plot of those averages). The observed relationship, in general, is that the 16-year monthly average volatility starts out low in May, increases through the peak volatility in September, and decreases through the end of the contract. This is the same general seasonal pattern observed in grains with the exception that the peak in volatility occurs later in cotton (August and September) than in feed grains (July) (Hennesey and Wahl, 1996). It can also be seen that there is variation in the volatility from year to year.

Figure 2 shows the monthly volatilities over the 1982 to 1997 period, which reflects the data found in Table 1. Volatility exhibited a sharp peak during 1986, which corresponds to the Inventory Protection Certificate period. During this period, holders of cotton were provided protection by the government for downward price movements as much of the U.S. stocks of cotton were liquidated. This period was characterized by large downward movements in price over the growing season as stocks were liquidated, with considerable price recovery at the end of the growing season and some spillover into 1987. The same general seasonal pattern in volatility was observed in 1986 as in other years (Table 1), but the magnitudes of the volatilities were significantly magnified.

Price Volatility Model

The general model of price volatility used in this analysis is:

$$VOL_i = f(TTM, P, Policy, SEA, W, SD),$$

where VOL_i is the volatility for month i as defined in equation 1, TTM is the number of months to contract maturity or "time-to-maturity," P is the futures price, Policy is a vector of policy variables, SEA is a vector of seasonal variables, W represents weather effects, and SD are potential supply/demand effects on volatility.

The specification of the price relationship deserves attention. The relationship between volatility and price suggests a non-linear relationship. Previous empirical work (e.g., Streeter and Tomek, 1992) have found a direct linear relationship between the futures price and price volatility. Taken with the above mathematical relationship, this might suggest a relationship that in increasing at an increasing or decreasing rate. A quadratic specification of the price variable is used to allow for the potential non-linearity in this empirical model of cotton price volatility.

Agricultural policy also has the potential to affect price volatility. For example, some have hypothesized that movement toward more "market-oriented" policy is expected to increase price volatility (Ray et al., 1998), while others argue that this expectation is not necessarily true (Collins and Glauber, 1998). To account for potential changes in price volatility due to policy changes, a series of dummy variables for the years of each farm legislation is used. That is, P85 (1985 Farm Bill)=1 if the year is 1985 through 1989, and P85=0 otherwise. Likewise, P90=1 if the year is 1990 through 1995 and P90=0 otherwise. Finally, P96=1 if the year is 1996 or 1997 and P96=0 otherwise. The period 1982 through 1984 is used as the base period. All these agricultural policies have counteracting effects. For example, increasing loan rates and acreage reduction allocations might be expected to have different effects on volatility. Thus, coefficients on these dummy variables represent the "net" effect of policy on price volatility.

Another important agricultural policy is the non-recourse or Commodity Credit Corporation (CCC) loan rate. The loan rate is expected to decrease volatility, other things equal, because it limits the downward movement in price. The loan rate is included in this model to account for the potential dampening effect on price volatility that this government policy may have.

Seasonality is another important factor for volatility that has been identified in the literature. Dummy variables for each month are used in this analysis. Others have used a series of sine and cosine variables (e.g., Streeter and Tomek, 1992; Goodwin and Schnepf, 1998). However, only the growing season volatility (May to December) is used in this analysis, thus interrupting the continuity of the sine and cosine variables. Others such as Kenyon et al. (1987) and Hennesey and Wahl (1996) have successfully used dummy variables to capture the seasonality of volatility. The months of May and December are used as the base months.

Weather is an important determining factor of crop condition, and thus, price volatility. The weather variable used in this analysis relates to temperature because temperature (as reflected in heat degree days) is important in determining cotton yields and maturity. Monthly average temperatures in three important cotton producing areas (the Delta Region of Mississippi, Lubbock, TX, and the San Joaquin Valley, CA) were collected from the National Oceanographic and Atmospheric Administration's database for the period of analysis. A weighted average temperature was calculated for each month over the period of analysis (weighted by the number of harvested acres in each state). Then, a simple average for each month was taken across the period of analysis, resulting in one average temperature for May, one for June, etc. A monthly temperature deviation was constructed by:

$$TD_{i,t} = Temp_{i,t} - \overline{Temp_i},$$

where $TD_{i,t}$ is the deviation of the temperature in month i at time t from month i's average temperature over the entire study period. This specification should (1) signal major deviations in temperature from a longer-run average and (2) eliminate the seasonal variation in temperature, thus limiting correlation with the seasonal dummy variables.

Finally, supply and demand factors may have an impact on price volatility. There are a variety of approaches to specifying these variables from the level of exports to monthly or quarterly disappearance data. The variable used in this analysis is the monthly deviation of the stocks to use ratio (SUD) from its monthly average. As above, the monthly stocks to use ratio was averaged for each month across the data set, resulting in an average stocks to use for May, June, etc. Then, the mean for each month was subtracted from each respective observation. This should eliminate seasonal variation in the stocks to use as stocks decline over the growing season and then rise as harvest begins. An advantage of this specification is that it reflects the relative supply/demand situation at each point in time relative to the typical year. When the stocks to use is higher than average, one would expect lower volatility, and *vice versa*.

One issue with the SUD variable is timing. When stocks to use data are released, they reflect the values for the previous month (except for forecasts). If traders utilize this information, they are making decisions based on what the supply/demand situation was the previous month. Thus, the SUD variable is lagged by one month in this model to reflect the time lag in information entering the market.

Data on closing prices for each day of each December contract for the period May 1 through the close of the contract were collected from the *CRB-Bridge* database and used to calculate volatilities and monthly average price (the data reflected in Table 1). Data on the stocks to use ratio were taken from the *Cotton and Wool Situation and Outlook* reports published by the Economic Research Service of the U.S. Department of Agriculture.

Examination of Table 1 reveals that 1986 showed significantly higher price volatilities than any other year. This reflects the effects of the Inventory Protection Certificates issued by the government. These certificates allowed price to "fall through the floor" set by loan rates as the government liquidated government stocks of cotton. As such, it would be difficult to discern whether the volatility that occurred within that year would have occurred without the government intervention. For that reason, the 1986 crop year data are omitted from estimation. In the same regard, some of the effects of this government intervention spilled over into the early part of the 1987 crop year. To control for this, a dummy variable for 1987 is included in the estimated model.

Proper estimation technique is a matter of some debate. Many authors have utilized Ordinary Least Squares (OLS) or Generalized Least Squares (GLS) regression (Streeter and Tomek, 1992; Kenyon et al., 1987; Hennesey and Wahl, 1996). The use of OLS regression is appealing because of ease of estimation. The finding of autocorrelation is common in these studies, but correction is relatively straight forward.

There may be reason, however, to expect that the error variance from the estimated equation of price volatility may not be constant through time, resulting in heteroskedastic error terms (Harvey, 1976). Additionally, some have observed that this heteroskedasticity tends to occur in concurrent periods. Fackler (1986) describes this as the "clumpiness" of information entering the market. That is, information tends to enter the market in batches, creating periods of high volatility that tend to persist for some time. This results in autocorrelated error terms. This observation has led to the application of autoregressive, conditional heteroskedasticity (ARCH) models introduced by Engle (1982) and generalized ARCH (GARCH) models presented by Bollerslev (1986) (see, e.g., Goodwin and Schnepf, 1998).

A general specification of an ARCH model is:

$$Var(e_t) = \sigma_t^{\,2} = \alpha_o + \sum_{i=1}^{k} \alpha_i e_{i-1}^2 + Z_i \gamma,$$

where e_t is the error resulting from the volatility model and its variance is F_t^2, e_{t-i}^2 are the lagged squared error terms from the volatility model, Z_i is a vector of variables related to the heteroskedasticity of the error term, and "'s and ('s are unknown parameters. The simplest specification Z_i is to use a column of ones. This form, discussed by Harvey (1976) and used by Goodwin and Schnepf (1998), returns the mean of the error variance. The GARCH model is as above with the addition of lagged predicted error variances coming from equation 5. Both the ARCH and GARCH models account for potential autocorrelation and heteroskedasticity in the error structure of the price volatility model.

As Engle (1982) points out, autocorrelation and heteroskedasticity are signs of model mis-specification (an omitted variable). The optimum is to properly specify the volatility model and estimate the equation using OLS. Nevertheless, the ARCH and GARCH models allow researchers to estimate equations that take proper account of potential violations of OLS assumptions. Thus, the equation of price volatility for cotton is estimated using both OLS and ARCH/GARCH estimation techniques and results are compared.

Results

Ordinary Least Squares estimates showed signs of significant first order autocorrelation as was found in previous analyses of volatility. Corrections for autocorrelation were made using the maximum likelihood procedure, and these results are presented in Table 2. The anticipated seasonal pattern in volatility is present, with August and September being the peak months in volatility. The market is likely attempting to assess crop size and harvest progress with harvest beginning in these months, increasing the potential for price volatility.

The temperature variable is marginally significant, indicating that the deviation of monthly temperature from that month's average temperature does have some relationship to volatility. The sign of the coefficient for that variable indicates that above average temperature leads to lower volatility, but the magnitude is small. This suggests that small deviations in temperature from the average do not have a large impact on volatility. This finding is likely related to the relative geographic dispersion of cotton production. That is, localized (particular region) deviations in temperature will have a small impact on the weighted average deviation in temperature across the Cotton Belt (Southern United States). Likewise, these local deviations in temperature will likely have a small impact on the overall yield of cotton in the U.S. Thus, small deviations in the temperature from the average would be expected to have a relatively small impact on price volatility.

The loan rate has a significant inverse relationship with volatility as expected. This suggests that the existence of the loan rate, other things equal, tends to decrease the level of volatility of cotton prices. However, the marginal impact of increases in the loan rate is small. A 1 ¢/lb increase in the loan rate is only expected to decrease the volatility of cotton prices by 0.55%. Thus, varying the loan rate would not be expected to increase or decrease the volatility of cotton prices substantially. This result, however, should be interpreted with caution because there has not been significant deviation in loan rates over time.

One interesting result is with regard to the effects of policy. These results suggest that there have not been any significant changes in volatility with regard to changes in farm policy when controlling for the effects of other variables. Thus, it appears that the hypothesis of moving to more "market-oriented" policies will increase volatility can be rejected, at least for cotton. This is consistent with the supposition of no real increase in volatility for cotton with the implementation of the FAIR Act put forward by Ray et al. (1998).

After controlling for all other variables, there does not appear to be a significant time-to-maturity effect in the harvest contract for cotton. This result is consistent to those of Hennesey and Wahl (1996) who found no time-to-maturity effect for grains after controlling for other variables. This suggests that there is no simple increase in volatility as contract expiration is approached when other factors are considered. This result, however, may be different if the time period before the growing season (before May) is considered.

There appears to be a significant non-linear relationship between price and volatility. Figure 3 shows this relationship with all other variables held at their mean levels. The convex relationship between price and volatility was not expected, but has some intuitive appeal. This relationship suggests that volatility at "low" and "high" prices tends to be significantly higher than in the mid-range. Traders likely keep a subjective estimate of the long-run expected price for cotton. Prices around that mean level would not be expected to move significantly, other things equal, leading to an expectation of lower volatility. As prices diverge from the expected (mean) level, traders begin to anticipate movement back to the mean. This anticipation likely makes the traders more sensitive to information that may move price, leading to increased levels of volatility. Extreme distance between the price and the mean likely exacerbates the anticipation and sensitivity to new information. Thus, it appears possible to have high volatility at both low and high prices.

It is possible that this relationship exists only for cotton. Evidence on the price relationship to volatility in other commodities was not derived because it was beyond the scope of this study. This finding, however, does raise the question of whether this is a general price relationship or whether this non-linear relationship is isolated to the cotton market. Further research in this area is necessary before general conclusions can be drawn.

The results of the ARCH/GARCH model of volatility are presented in Table 2. The same general relationships are observed as with the OLS estimates. Statistical significance for some variables was decreased, but the non-linear price relationship and seasonal effects remain. This is somewhat different from the results of Goodwin and Schnepf who found that inclusion of the ARCH/GARCH effects significantly changed the form of their model. The primary difference between the OLS and ARCH/GARCH models is that the lagged stocks to use ration (SUD_{t-1}) is dropped to achieve convergence in the maximum likelihood estimates in the ARCH/GARCH model. There is a significant one period ARCH effect, but no significant GARCH effect. There is also significant heteroskedasticity (Z_i(in equation 5).

The fact that the signs and statistical significance remain intact in the presence of the ARCH and heteroskedasticity effects lends some degree of confidence to the interpretations of the OLS estimates. However, the existence of the ARCH effect may be indicating some degree of model mis-specification (an omitted variable). This may be related to missing information about international conditions. That is, cotton is a widely traded commodity and is produced in significant amounts around the world. The lack of data on international conditions makes testing this hypothesis difficult at best. Nevertheless, it is a plausible explanation for these findings.

Conclusions

This analysis points to several general conclusions regarding harvest contract volatility in cotton. First, seasonality is an important relationship in cotton price volatility as with other major commodities. The existence of this seasonal relationship is expected and can have implications for timing of hedges by cotton producers. That is, placing hedges in times of more price volatility may lead to less than optimal prices in that price volatility implies that the market is attempting to establish to proper future price. Thus, hedging during the times of higher volatility may result in sub-optimal hedge prices.

A second conclusion is that changes in farm policy do not appear to have significantly changed price volatility levels for cotton. This is consistent with other work (Ray et al., 1998) and does not support the hypothesis that the 1996 farm legislation has increase price volatility in cotton. This does not say, however, that price volatility will not increase. The results of this analysis simply suggest that volatility has not shown signs of any increase to this point.

The specification of the policy effects necessarily limits conclusions about which components of the policy affected volatility. Certain components of policy such as acreage set asides have been shown to affect farm income volatility (Zulauf, 1998). Estimating the impact of the components of farm programs on volatility may be desirable in the future as future changes in price volatility are considered.

Finally, the results of this analysis suggest that a non-linear relationship between price and volatility does exist in the cotton market. This relationship may derive from a mean-reverting relationship that has been found to exist in cotton (Chen, Elam, and Ethridge, 1995). That is, deviations from the mean price generates expectations of movement toward the mean. These expectations likely increase market sensitivity to new information, thus increasing volatility. This finding suggests a need to examine the price/volatility relationship in other commodities as well. If a non-linear relationship does exist between price and volatility, this would certainly have implications for optimal hedge ratios at different price levels, and could have implications for crop insurance as well.

References

Anderson, R. (1985). "Some Determinants of the Volatility of Futures Prices." *The Journal of Futures Markets*, 5: 331-348.

Anderson, R. and J. Danthine. (1983). "The Time Pattern of Hedging and the Volatility of Futures Prices." *Review of Economic Studies,* 50: 249-266.

Benninga, S., R. Eldor, and I. Zilcha. (1983). "Optimal Hedging in the Futures Market Under Price Uncertainty." *Economics Letters*, 13: 141-145.

Bollerslev, T. (1986). "Generalized Autoregressive Conditional Heteroskedasticity." *The Journal of Econometrics*, 31: 307-327.

Chen, C., E. Elam, and D. Ethridge. (1995). "Historical Pricing Inefficiency in Cotton Futures: Implications for Hedging Strategies and Profits." *Beltwide Cotton Conferences, Proceedings, Addendum*, Cotton Economics and Marketing Conference, National Cotton Council, Memphis, TN, pp. 96-99.

Collins, K. and J. Glauber. (1998). "Will Policy Changes Usher in a New Era of Increased Agricultural Market Variability?" *Choices*, Second Quarter, pp. 26-29.

Engle, R. (1982). "Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of United Kingdom Inflation." *Econometrica*, 50: 987-1006.

Fackler, P. (1986). "Futures Price Volatility: Modeling Non-Constant Variance." Paper presented at the Annual Meetings of the American Agricultural Economics Association, Reno, NV.

Feder, G., R. Just, and A. Schmitz. (1980). "Futures Markets and the Theory of the Firm Under Price Uncertainty." *Quarterly Journal of Economics*, 44: 317-328.

Glauber, J. and R. Heifner. (1986). "Forecasting Futures Price Variability." Applied Commodity Price Analysis, Forecasting, and Market Risk Management, *Proceedings of the NCR-134 Conference*, St. Louis, MO., pp. 155-165.

Goodwin, B. and R. Schnepf. (1998). "Determinants of Endogenous Price Risk in Agricultural Markets." Paper presented to an Organized Symposium on Price Risk at the Annual Meetings of the American Agricultural Economics Association, Salt Lake City, UT.

Grant, D. (1985). "Theory of the Firm with Joint Price and Output Risk and a Forward Market." *American Journal of Agricultural Economics*, 67: 630.635.

Harvey, A. (1976). "Estimating Regression Models with Multiplicative Heteroskedasticity." *Econometrica*, 44: 461-465.

Heifner, R. (1973). "Hedging Potential in Grain Storage and Livestock Feeding." Agricultural Economics Report 238, U.S. Department of Agriculture, Washington, DC.

Heifner, R. (1997). "Can Option Forecast Crop Price Volatility over the Growing Season?" Selected Paper presented at the Annual Meetings of the American Agricultural Economics Association, Toronto, Canada.

Hennesey, D. and T. Wahl. (1996). "The Effects of Decision Making on Futures Price Volatility." *American Journal of Agricultural Economics*, 78: 591-603.

Hull, J. (1997). *Options, Futures, and Other Derivatives*. Third Edition, Prentice Hall Publishers, Upper Saddle River, NJ.

Irwin, S., C. Zulauf, and T. Jackson. (1996). "Monte Carlo Analysis of Mean Reversion in Commodity Futures Prices." *American Journal of Agricultural Economics*, 78: 387-399.

Kahl, K. (1983). "Determination of the Recommended Hedging Ratio." *American Journal of Agricultural Economics*, 65: 603-305.

Kenyon, D., K. Kling, J. Jordan, W. Seale, and N. McCabe. (1987). "Factors Affecting Agricultural Futures Price Variance." *The Journal of Futures Markets*, 7: 73-91.

Knight, T. and K. Coble. (1998). "Survey of U.S. Multiple Peril Crop Insurance Literature Since 1980." *Review of Agricultural Economics*, 19: 128-156.

Lapan, H. and G. Moschini. (1994). "Futures Hedging Under Price, Basis, and Production Risk." *American Journal of Agricultural Economics,* 76: 465-477.

Lence, S. and D. Hayes. (1994). "The Empirical Minimum-Variance Hedge." *American Journal of Agricultural Economics*, 76: 94-104.

McKinnon, R. (1967). "Futures Markets, Buffer Stocks, and Income Stability for Primary Producers." *Journal of Political Economy*, 75: 844-861.

Moschini, G. and H. Lapan. (1995). "The Hedging Role of Options and Futures Under Joint Price, Basis, and Production Risk." *International Economics Review*, 36: 1025-1049.

NASS. Various Issues. "Crop Progress Reports." U.S. Dept. of Ag., National Agricultural Statistics Service, Washington, DC.

Ray, D., J. Richardson, D. De La Torre Ugarte, K. Tiller. (1998). "Estimating Price Variability in Agriculture: Implications for Decision-Makers." *Journal of Agricultural and Applied Economics*, 30: 21-33.

Sakong, Y., D. Hayes, and A. Hallam. (1993). "Hedging Production Risk with Options." *American Journal of Agricultural Economics*, 75: 408-415.

Samuelson, P. (1965). "Proof that Properly Anticipated Prices Fluctuate Randomly." *Industrial Management Review*, 6: 41-49.

Stein, J. (1979). "Spot, Forward and Futures." *Research in Finance*, 1: 225-310.

Streeter, D. and W. Tomek. (1992). "Variability in Soybean Futures Prices: An Integrated Framework." *The Journal of Futures Markets*, 12: 705-728.

Zulauf, C. (1998). "Will Policy Changes Usher in a New Era of Increased Agricultural Market Variability?: A Comment." *Choices*, Third Quarter, p. 44.

Table 1. Percentage Annualized Volatilities in the December Futures Contract for Cotton, 1982-1997.

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1982	4.36	7.92	7.48	7.63	6.62	5.20	5.56	4.60
1983	6.84	9.34	8.60	8.30	8.32	5.99	7.40	5.16
1984	6.31	6.14	6.28	6.43	4.15	7.26	7.56	2.20
1985	5.73	4.69	6.35	4.81	3.21	4.59	4.89	3.71
1986	10.6	8.27	15.1	14.3	24.4	16.0	15.0	13.3
1987	9.96	13.4	7.61	9.71	11.5	10.5	13.1	12.0
1988	11.5	15.5	9.43	11.3	12.0	11.7	9.94	9.14
1989	5.03	10.5	6.39	8.41	9.35	6.72	8.33	12.4
1990	4.46	5.31	8.71	7.93	7.40	5.71	7.77	1.95
1991	8.61	8.94	8.26	9.61	8.73	7.48	11.9	7.73
1992	9.46	8.58	7.29	11.5	9.73	9.56	11.4	4.15
1993	4.92	4.79	10.2	10.1	8.82	6.82	8.27	8.26
1994	4.74	7.27	10.7	9.80	7.44	8.08	8.45	16.1
1995	10.6	10.4	10.4	12.5	15.8	12.0	7.74	6.86
1996	7.98	7.06	6.77	10.8	10.3	8.54	7.01	7.44
1997	2.76	5.49	5.93	4.69	6.41	3.99	5.96	10.5
Avg.	7.11	8.35	8.47	9.24	9.63	8.14	8.77	7.85

Table 2. Result from the Estimated OLS and ARCH/GARCH Models of Price Volatility in the Harvest Contract for Cotton.

Variable	OLS Estimate	ARCH/GARCH Estimate
Intercept	85.15*	105.23*
Error Variance (Z()	3.65*	
TTM	-0.02	-0.02
Futures	-1.41*	-1.93*
Futures^2	0.01*	0.01*
Loan	-0.55*	-0.59*
June[a]	1.36**	1.53*
July	1.19**	1.42**
August	1.53*	1.65*
September	1.39*	1.13
October	0.24	0.11
November	0.92	1.12
P85	-0.17	-0.92
P90	-1.15	-1.20
P96	-1.17	-1.24
SUD_{t-1}	-0.06	
TD	-0.17**	-0.16
Y87	2.89*	3.53*
AR(1)	-0.20*	
AR(2)	-0.05	
ARCH(0)	0.00*b	
ARCH(1)		0.22
GARCH(1)	0.00[b]	
R^2	0.46	0.41
Log Likelihood	-253.88	-258.16

* indicates statistical significance at the 0.05 level or better.
** indicates statistical significance at the 0.10 level or better.
[a] monthly dummy variables.
[b] number smaller than 0.00.

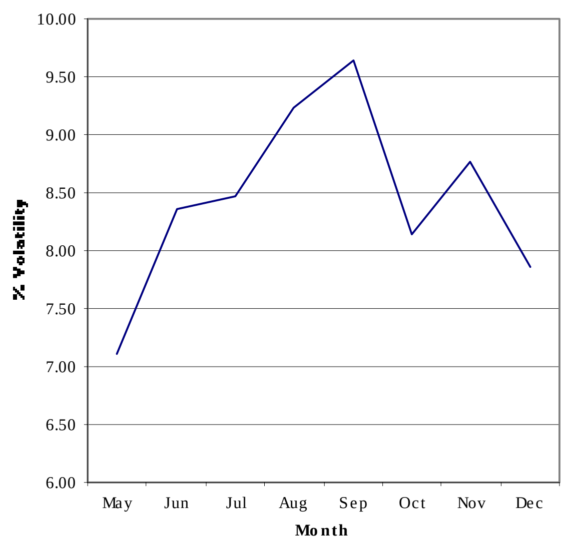

Figure 1. Monthly Average Price Volatility, December Contract, 1982-1997.

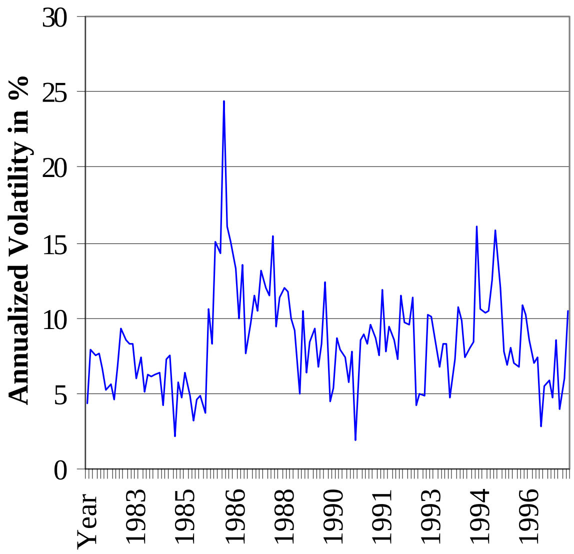

Figure 2. Annualized Monthly Price Volatilities by Month, 1982-1997.

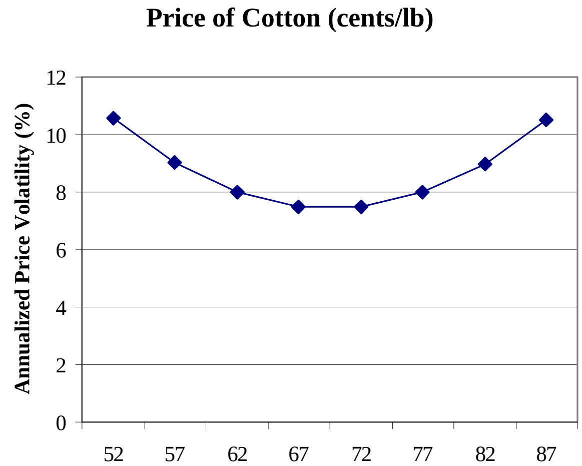

Figure 3. Predicted Relationship between Cotton Futures Price and Futures Price Volatility.