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An Integrated Model of Variability in Live Cattle Futures Prices

Kevin J. Evans, Deborah H. Streeter, and Michael A. Hudson*

An understanding of how price volatility changes over time is of interest to policy makers as well as various participants in commodity markets. Knowledge about the source of price variability can be useful to risk managers making decision about the timing of their positions. Margins set by exchange committee members depend, in part, on price volatility. Also, the premium paid for an option is influenced by changes in price volatility for the underlying futures contract.

The primary goal of this paper is to explore how various forces impact the volatility of futures prices for live cattle by extending previous research in which volatility was viewed as a function of market structure and information flows. Market structure relates to the effects of liquidity and concentration while information flows refer to how the timing of information coming into the market affects volatility. Streeter and Tomek (1991) suggest an integrative framework which encompasses these influences in measuring volatility of soybean futures prices. For the soybean market they found that the model combining information flows and market structure performed better on specification tests than models focusing on either market structure or information flow variables alone.

The current paper applies the integrative framework suggested by Streeter and Tomek to examine volatility in the April live cattle futures contract. With this approach, various economic, market structure, and information flow factors which influence the volatility of price over time can be examined. The study of the live cattle contract allows the opportunity to test the integrative framework on a non-storable, thinly traded commodity. The performance of the model on various specification and stability tests is used to evaluate the model and a comparison with models which do not use the integrative framework is made.

In addition to providing insights about the causes of volatility in live cattle markets, the forecasting value of the model is examined. Specifically, the results of the model are used to forecast volatility in order to determine premiums for live cattle options. Performance of the model is compared against a naive forecasting model.

The paper begins with a review of related literature, followed by the specification of a general model. The empirical model is then discussed including a discussion of specific variables. Next, the estimation of the model and the results from the model are presented. Finally, the model's performance on the specification tests and its ability to forecast are discussed.

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Previous Research

Previous studies of price volatility have generally concentrated on measuring variability by emphasizing either market structure variables or information flow variables. For example, work on the effects of market structure variables has focused primarily on how volatility is affected by speculative activity. Ward (1974) reported that although the probability was low, excess speculation could occur in the frozen concentrated orange juice market. Peck (1981) studied volatility for wheat, soybeans, and corn from 1964 to 1978 by measuring the monthly average of the daily trading range of the nearby futures contract. Peck found that as speculation in the three markets decreased relative to hedging, volatility may have increased. Peck concluded that during this period, a growth in hedging may have strained the capacity of each market and that speculation could be inadequate, causing increased price variability in the markets.

Using the same variables as Peck, Leuthold (1983) found the same relationship between speculation and volatility in livestock markets. Leuthold determined that increased speculative activity is associated with intraday price stability. Leuthold also studied the correlation between speculators and hedgers and concluded that speculators enter and exit livestock markets in response to hedging needs.

Other work focusing on market structure effects includes Brorsen and Irwin (1987), who studied how the use of futures funds and their reliance on technical trading affected volatility in 10 different commodities. The study was motivated by concerns that excessive swings in market price could be created due to large sums of capital trading on the same system in the same commodity. The authors found that technical trading is not a significant factor in measuring futures price volatility.

Another line of research has explored the impact of information flows on price volatility. Samuelson (1965) theorized that as a futures market contract approaches maturity, price volatility for that contract will increase because more and more relevant information is revealed. Various studies found evidence supporting the Samuelson effect, including, Miller (1979), who studied daily price changes in the live cattle futures market and Milonas (1984), who examined 11 commodities.

Anderson (1985) suggested that the Samuelson effect is a special case encompassed by the broader concept of the state variable hypothesis developed by Anderson and Danthine (1983). The state variable hypothesis shows that the *ex ante* variance of futures prices is high in periods when relatively large amounts of supply and demand uncertainty are resolved. In an examination of 9 commodities, including live cattle, Anderson found that both seasonality and the Samuelson effect are highly significant for volatility in live cattle futures prices. The author concluded that in general, the principle predictable factor for changes in variance is seasonality and the Samuelson effect is only a secondary influence.

Kenyon, et. al. (1987) considered the effects of seasonality on price variance in 5 agricultural futures markets. To determine which economic variables generate large fluctuations in volatility from year to year, the authors included the level of production for

livestock commodities and the level of futures prices relative to the loan rate for grain markets. Kenyon, et. al. concluded that seasonal patterns are significant for grain commodities but not for livestock markets. Furthermore, they found that while price volatility can reasonably be assumed constant in livestock futures markets over the life of a contract, the same conclusion cannot be made for grain markets. Glauber and Heifner (1986) found similar results for seasonality in the soybean markets.

In contrast to previous studies which tended to focus only on one category of explanatory variables, Streeter and Tomek included both market structure and information flow variables in an attempt to specify a more integrated model of the variance of changes in futures prices. The authors analyzed the November and March soybean futures contracts for the period from 1976 to 1986. The results of the study agreed in general with previous work in which market structure and information flow variables were dealt with separately. However, Streeter and Tomek found that the integrated model performed better on specification tests than less inclusive models. In addition, a nonlinear Samuelson effect was found for soybean futures.

Previous literature shows that volatility in live cattle futures prices is affected by market structure and information flow type variables, suggesting that an integrative framework can be beneficial to explain volatility in this market. Therefore, the general model of volatility in the current paper uses the integrative framework proposed by Streeter and Tomek, by utilizing variables which represent market structure, information flow, and economic information.

The Model

Price volatility is caused by the adjustments in price levels which occur during the price formation process. When such adjustments are large and/or change frequently in direction, price volatility is increased. Thus, high volatility is not necessarily associated with increases or decreases in prices per se, but rather with the magnitude and fluctuation of price changes. Accordingly, volatility in futures prices can be measured by the variance of changes in price. Based on the Streeter-Tomek framework, the general model to be estimated is:

$$Vit = F\ (I_{it},\ E_{it},\ MS_{it}),$$

where,

V_{it} = Volatility of futures price in month i for contract year t,
I_{it} = Information flow effects
E_{it} = Economic information effects, and
MS_{it} = Market structure effects.

The general model reflects the fact that various elements can influence the price adjustments which lead to volatility. The most fundamental reason for a change in prices is the flow of new information into the market. The impact of information into the futures market is conditioned by previous expectations, the certainty of the information, and existing supply and demand factors. For example, changes in the number of cattle on feed may be

anticipated well before the official report is released by the USDA. If expectations are correct, the report itself will be old news, but if the market incorrectly anticipates information in the report, changes in official supply estimates can generate increases in price volatility as the market sorts out the meaning of the new information. The certainty of the information also varies seasonally with the production cycle. Finally, price adjustments depend in part on the general economic environment. Volatility depends, in part, on whether current inventories are small or large relative to current demand.

In addition to information flows and economic variables, price adjustments in futures markets may also be affected by the size and composition of players in the futures market. Livestock producer groups occasionally have raised the question as to whether the presence and activities of speculators introduce unwarranted price volatility. Presumably, increased variability might occur if speculative activity is too large relative to hedging activity. Another relevant aspect of market structure is the effect of large traders, either speculators or hedgers, whose market activity might introduce erratic price adjustments, since their trades can be of a magnitude sufficient to move the market above or below a level justifiable based on supply/demand factors.

An empirical model was developed which takes into account the aspects of the general model through the use of variables representing market structure, information flow, and economic effects on volatility in live cattle futures prices. Mean values and standard deviations for all variables in the model are reported in Table 1.

Previous studies have measured volatility in a variety of ways, including, the monthly average of the daily range (Peck; Leuthold) or the variance of the natural log of daily price changes over a month (Anderson; Milonas; Glauber and Heifner; Streeter and Tomek). In this study, the dependent variable is calculated in the same manner as the historical volatility measure used in the Black option pricing model: the annualized standard deviation of the natural log of the daily change in futures price over monthly intervals (Kenyon, et. al.):

$$V_{it} = \sqrt{\frac{\sum_{i=1}^{n} (R_{it}-R)^2}{(n-1)}} * 256$$

where,

V_{it} = Historical Volatility
$R_{it} = \ln F_i - \ln F_{i-1}$
R = Mean of R_i for n days
i = Days
n = Number of Observations per Month
t = Contract Year
256 = Number of Trading Days in a Year.

Market structure variables are intended to reflect the speculative activity of position traders and scalpers as well as the presence of large players in the market (either hedgers or

speculators). Position trading is measured using a version of Working's speculative index suggested by Peck.[1] Based on data from the CFTC's Commitment of Traders Monthly Report, the speculative index is calculated as:

$$1+\frac{SS}{HS+HL} \quad when\ HS \geq HL, \quad 1+\frac{SL}{HS+HL} \quad when\ HS < HL$$

where,

SS = Short Speculation
SL = Long Speculation
HS = Short Hedging
HL = Long Hedging.

The speculative index measures the amount of speculation relative to hedging use. Thus, as the index gets larger, speculation grows larger relative to hedging. Peck, Leuthold, and Streeter and Tomek found that the speculative index has an inverse relationship to volatility.

No data source is available on a continuous basis for scalping activity, so the use of a proxy variable is required. Following the convention of other studies (Peck, Streeter and Tomek), scalping is measured by the monthly average of daily total volume relative to open interest of all contract months.[2] Previous studies found scalping to be positively related to volatility, contrary to expectations that increased liquidity from scalping would decrease volatility.

To reflect the impact large players have on price volatility, the model includes two market concentration measures: the percentage of open interest held by the four largest long traders and the percentage held by the four largest short traders for all live cattle contracts. The source for the concentration ratios is the Commitment of Traders Report. The meat packing industry is dominated by a few large firms who can benefit from directional changes in price. Large traders have potential to move the market through superior access to information or to manipulate the market through the size of their position (Ward, 1987), even though the market must eventually return to a price level consistent with the underlying supply and demand factors. Thus, the expectation is that concentration measures are positively related to volatility.

Information flow variables include the time-to-maturity variable (to reflect the Samuelson effect) and seasonal variables. The time-to-maturity variable is measured as the

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[1] For a description of Working's speculative index see Peck (1981). Nonreporting traders are allocated as speculators. The CFTC did not publish these reports from December 1981 to November 1982, so forecasts for the missing data were made over this period. Also, the CFTC changed its reporting procedures in December 1982. Dummy variables were used to account for these changes, but were not significant and are not reported.

[2] In previous studies the data was not aggregated to form this variable. It is justified here because volume relative to open interest for a single contract has the tendency to simply trend upward over the life of the contract. Also, the aggregated data is consistent with the other measures of market structure taken from the CFTC in that they are only available in measurements of all contracts combined.

number of months left until maturity. If the Samuelson effect holds, then as the contract approaches maturity, volatility should increase. Under the state variable hypothesis this is explained by the fact that as the contract approaches maturity, more information is revealed about the commodity and volatility increases. For example, in the live cattle contract information on the actual number of cattle available to fulfill the contract is more accessible 3 to 5 months prior to maturity than 10 to 12 months because the cattle which fulfill the contract are not committed to go on feed until approximately 6 months before maturity. Thus the sign on the time-to-maturity variable is expected to be negative.

Seasonal effects are expected to influence price volatility of the live cattle contract. Harmonic variables are included to capture the seasonality created by the patterns of birthing, weaning, and placements on feed. Harmonic variables are used because they allow the possibility for a smooth seasonal effect with less than 11 variables (Doran and Quilky, 1972).

The existing economic environment conditions the reaction of prices to changes in information. To reflect the current economic setting, the model includes the closing price of the last day of the previous month . If the market is efficient, then the previous settlement price should take into consideration all supply and demand information available for the commodity. Another variable included to reflect economic conditions is the ending inventory from the 7 State Cattle-on-Feed report.[3]

The question arises as to whether a supply type variable is relevant to measure volatility. Since, in an efficient market, the futures price level should be the consensus of all supply and demand information, any supply or demand report should be taken into consideration by the price level. Under that condition any new information contained in the report can be considered redundant. In this case however, since the COF report comes out in the middle of the month new information should be available which is not reflected in the last price from the previous month.

Model Estimation and Results

To reflect the concepts of the general model of price variability, the empirical model was estimated using April live cattle futures over a sample period from January 1979 to December 1989.[4] The modeling process began by specifying a general model containing variables from each relevant conceptual category, as well as a lag structure containing 4

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[3] An alternate measure of current supplies would be the 13 State Quarterly COF report, as it reports the specific weights of animals available for contract fulfillment (Schroeder, et. al., 1990). One might also view monthly marketings as more appropriate than ending inventory, but marketings are more applicable when a contract is near expiration (Grunewald, et. al., 1991). However, neither of these variables performed well in the model. Other variables such as input costs (Koontz, et. al., 1992) and basis (Garcia et. al., 1984) can also potentially contribute information about volatility. These were not considered for this paper, but will be examined in future work on other live cattle contracts.

[4] The April futures contracts are linked from year to year so that each contract contains 12 months of data. Each contract begins in May of the previous year and ends in the expiration month. The last 4 days of the contract month are deleted to take out possible aberrant observations which might occur at maturity. This method of linking contracts is justified because trading is very thin in distant months.

period lags for all variables except time and seasonals.[5] Previous research shows that lagged regressors and autoregressive terms provide additional information to determine volatility in futures markets (Streeter and Tomek). The initial model was then simplified by systematically reducing insignificant lagged variables and the autoregressive structure.[6] The 11 sine and cosine seasonal variables were also reduced to two variables by methodically dropping those with low t-scores.

The final model contained the lagged dependent variable and variables reflecting market structure, information flows, and economic conditions. The results for the final model are presented in Table 2. The model appeared to perform in a satisfactory manner with an R^2 approximating that of previous literature and significant variables in the major categories that were discussed. Expectations were met in that the Samuelson effect holds for live cattle and shows a stronger effect than seasonal variables. The seasonal pattern, as reflected in Figure 1, is reasonable given the production pattern of live cattle.[7] The positive signs for the concentration variables were also in line with expectations.

The negative sign for the futures price suggests that as price increases, volatility declines; the positive sign on the inventory variable indicates that as inventory increases, so does volatility. These relationships differ from the results for storable agricultural commodities, however there were no *a priori* expectations about the signs of these variables and Kenyon et. al. found the same relationships in the live cattle market.

The positive sign on the speculative index is a major departure from the findings in previous studies.[8] The change in reporting procedures by the CFTC in 1982 is one possible explanation for this departure. Also, these variables are determined simultaneously, therefore increased volatility could draw more speculators into the market as well as vice versa (Garcia et. al., 1986; Leuthold). The positive sign on the scalping variable agrees with previous studies but remains a puzzle. It is likely that this is simply a poor proxy for the liquidity provided by scalpers.

In addition to the standard use of R^2, Durbin's h statistic, and t-statistics as measures

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[5] The 4 period lag structure was based on the judgement that futures prices adjust to new information swiftly so that all new information should be accommodated within this period of time.

[6] Streeter and Tomek used common factor nested tests (McAleer, 1985) to find that a model with one period lagged regressors and third-order autoregressive terms is appropriate for soybean futures. The tests showed that lagged regressors and autoregressive terms are not significant in the live cattle market.

[7] Figure 1 was developed holding all coefficients constant except for the time-to-maturity and two seasonal variables. It is interesting to note that relative high points occur in this plot during months when quarterly 13 State Cattle on Feed reports are released. Although the quarterly reports were not significant in the model, perhaps they are represented to some extent by the seasonal variables. When the model is extended to other contract months, this relationship will be examined further.

[8] In a model for live cattle comparable to the Peck model, positive signs for these variables were also found. In addition, the nonreporting traders were reallocated to the same percentage of speculation and hedging as reporting traders but the coefficient and its significance did not change.

to determine the appropriateness of the model, the equation was subjected to a battery of diagnostic tests.[9] The purpose for using diagnostic tests is to verify the overall adequacy of the model to explain volatility. There was no expectation that the model would pass all the tests, but the fact that the model performed well on most tests does give some reassurance that the model is specified correctly.[10]

Forecasting Option Premiums

One argument for performing analysis on volatility in futures markets is that the results will be useful to determine premiums for options on underlying futures contracts. It has been suggested that such a model could be used to make forecasts of volatility, which might then be used to predict options prices. In this section a two step process is used where first, historical volatility is forecast for 1990 using both the integrated model developed in this study and a naive model where volatility is measured by a constant and the previous months volatility. The second step is to obtain daily option premiums by inserting the forecasts for volatility into the Black option pricing model. Assuming that volatility remains constant over the course of a month, the daily option premiums from the integrated and naive model forecasts can be compared to actual premiums maturing in March 1990 and 1991.

The Black model is a theoretical formula used to calculate the fair price of an option on a futures contract given the underlying futures price, time to expiration, a risk free interest rate, and volatility of the underlying futures price.[11] Volatility is used in the development of the probability that the futures price will reach a specified strike price. The option premium depends, in part, on that probability.

In the forecasts for historical volatility from step one, the forecasts from the integrated model have an MSE of 0.0006 compared to an MSE of 0.0013 for the naive model. However, both models correctly predicted only 4 of 11 turning points.

For the second step, where the Black model is used to obtain daily option premiums,

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[9] Micro TSP was used to perform all of the regression analysis and contains the various diagnostic tests that were used to evaluate the model. The model passed the Ramsey Reset test, an ARCH test, and a serial correlation test. The model failed the Jarque-Bera test for normality of the residuals (the test showed that kurtosis was present in the residuals). Most of the variables performed favorably in recursive coefficient estimate plots. The best performances were from the seasonal variables, the time-to-maturity variable, the speculative index, and the ending inventory variable. The worst performances came from the short concentration variable, the lagged dependent variable, and the scalping variable. In a plot for a cumulative sum test the model briefly went outside the 5% significance boundary, but remained within the 5% significance boundary for the cumulative sum of squares test.

[10] Models similar to those developed by Peck and Kenyon et. al. were also analyzed using the diagnostic tests. These models did not perform as well as the integrated model showing that a more complete explanation of volatility is conveyed using an integrated framework.

[11] Information for use of the Black Model was taken from Bobin (1990) and Chance (1989). Options premium data was obtained from the Chicago Mercantile Exchange and the risk free rate is the daily 3 month Treasury Bill interest rate from Federal Reserve Bulletin G.13. Futures price data was obtained from Technical Tools.

plots of option premiums for the $76 strike price are shown in figures 2 and 3.[12] Turning point analysis showed that both the integrated and the naive model produced the same turning points for the $76 strike price and only 15 turning points were different over 989 observations for all the strike prices. This was probably due to other factors taken into consideration by the Black model. The turning point forecasts were 80% accurate for the option maturing in March 1990, 75% accurate for the option maturing in March 1991 and performed more accurately for strike prices closer to at-the-money. The naive model consistently had a lower MSE than the integrated model across all strike prices because the forecast from the integrated model was consistently smaller than either the naive forecast or the actual option premiums. For example, the MSE for the $76 call option maturing in March 1990 was 0.17 for the integrated model and 0.01 for the naive model.

The comparison of the integrated model to the naive model shows that the model has limited value for predictive purposes. It is likely that some other time series model would outperform the model. Thus, future studies should focus on the goal of understanding the relationship of volatility to the various explanatory variables, rather than expectations of successful point forecasts of options premiums.

Conclusions and Future Work

The goal of the paper was to develop an integrated model of volatility in the live cattle futures market. By looking at market structure, information flow, and economic variables in an integrated framework, a more complete model and a better understanding of the factors affecting volatility is revealed.

The methodology began with a model containing a large lag structure and systematically worked toward a smaller model. The final model contained only the lagged dependent variable and no autoregressive terms. The results of the specification tests indicate that the model is well-specified and stable. The outcome supports the Streeter and Tomek findings that the integrated model encompasses previous models which measure volatility through only market structure or information flow variables.

The results of the model show that the Samuelson effect exists in the live cattle futures market. Seasonality also helps to explain volatility, however the seasonal variables could be influenced by quarterly COF reports which contain more specific information than monthly reports. Volatility is increased by the activity of large traders (more by long traders than short traders). Also when speculation is large relative to hedging in the live cattle market, volatility increases.

The performance of the model to forecast option premiums shows that the predictive value of the model is no better than a naive model. However, the integrated model does

[12] The $76 strike price is shown because it is close to at-the-money throughout the forecast period. The plots in figures 2 and 3 show both puts and calls for the last 58 trading days of the option maturing in March 1990 and the last 53 trading days of 1990 for the option maturing in March 1991. Other strike prices produce similar results although strike prices far out of the money produce slightly poorer results.

provide a better understanding of how volatility reacts to changes in variables from the different categories.

Future work will center on the extension of this study to other contract months for th live cattle commodity. A comparison of the lag structure and relevance of the variables between contract months will provide insight into volatility in the live cattle futures market.

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Table 1. Definitions of Variables

Variable Name	Description	Mean[m]	Standard Deviation
HISTVOL	Monthly Normalized Standard Deviation of Daily Differences in Log Prices	0.1424	0.0543
LONG4	Monthly % Long Open Interest Held by 4 Largest Traders	8.0826	2.6971
SHORT4	Monthly % Short Open Interest Held by 4 Largest Traders	15.734	3.7462
SCALP	Monthly Aggregated Average of Daily Ratio of Volume to Open Interest	0.3174	0.0765
SPINDEX	Speculative Index	2.1531	0.3011
MEND	7 State Monthly Cattle on Feed Ending Inventory	7455.6	597.04
FUTPR	Last Day of Month Closing Futures Price	66.398	5.6110
COS4	Cosine of Fourth Harmonic Wave	0.000	0.7098
COS5	Cosine of Fifth Harmonic Wave	0.000	0.7098
TIME	Number of Months to Contract Expiration	5.500	3.4652

[m]Sample period is 79.01 to 89.12

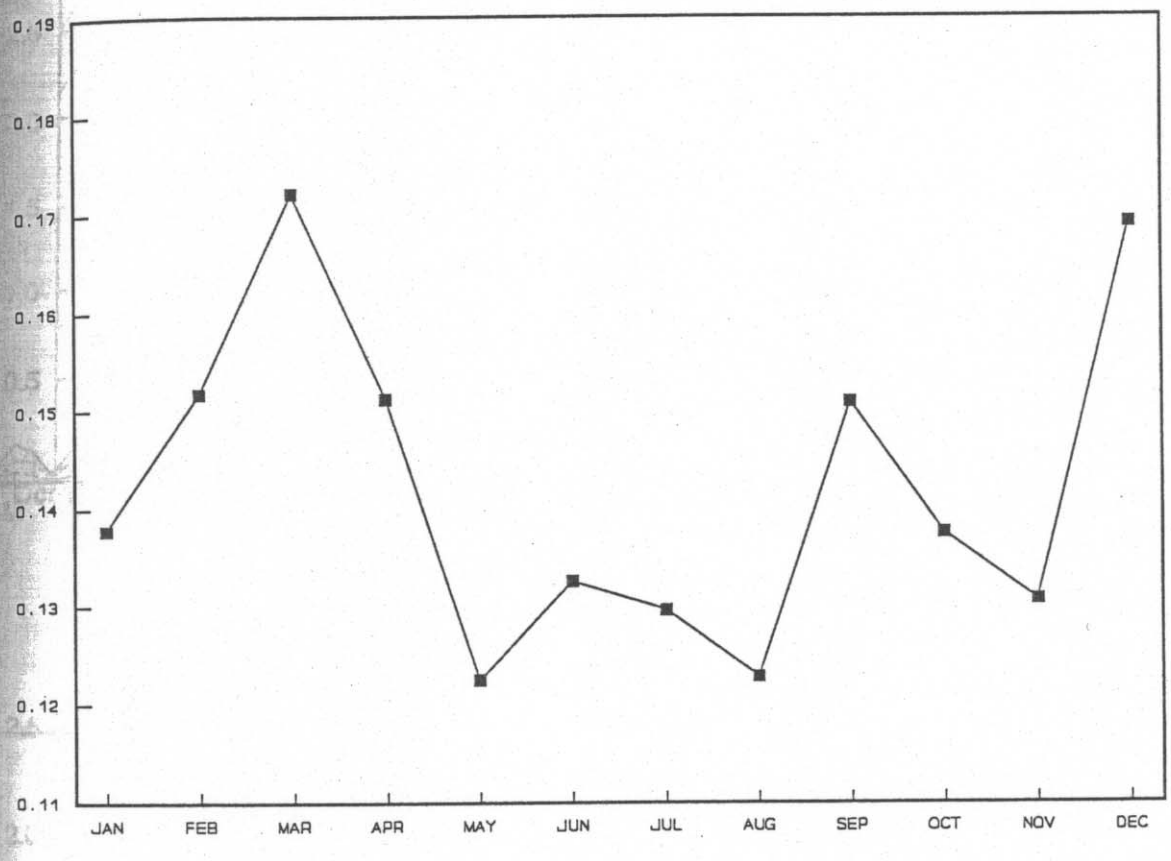
Table 2. Model for Historical Volatility

Dependent Variable: HISTVOL

Variables:	Coefficient	t-stat
CONSTANT	-0.0708	-1.0077
HISTVOL(-1)	0.0981	1.3483
Market Structure Variables:		
SPINDEX	0.0404	2.5316
SCALP	0.4486	7.8264
LONG4	0.0028	2.0048
SHORT4	0.0016	1.3520
Flow of Information Variables:		
TIME	-0.0035	-3.4952
COS4	0.0137	3.1921
COS5	0.0076	1.7564
Economic Variables:		
FUTPR(-1)	-0.0026	-3.9467
MEND	1.487E-05	2.4768

$R^2 = 0.637$
Adjusted $R^2 = 0.607$
Durbin's h Statistic = 0.428
F-Statistic = 21.231
N = 132 (1979.01 - 1989.12)

Figure 1. Seasonal and Time-to-Maturity Changes in Volatility for April Live Cattle Futures Prices for the Period from January 1979 to December 1989



* All variables are held constant except for COS4, COS5, and TIME

Figure 2. Comparisons of Integrated and Naive Model Forecasts to Actual Option Premiums for an At-the-Money Strike Price with March 1990 Expiration

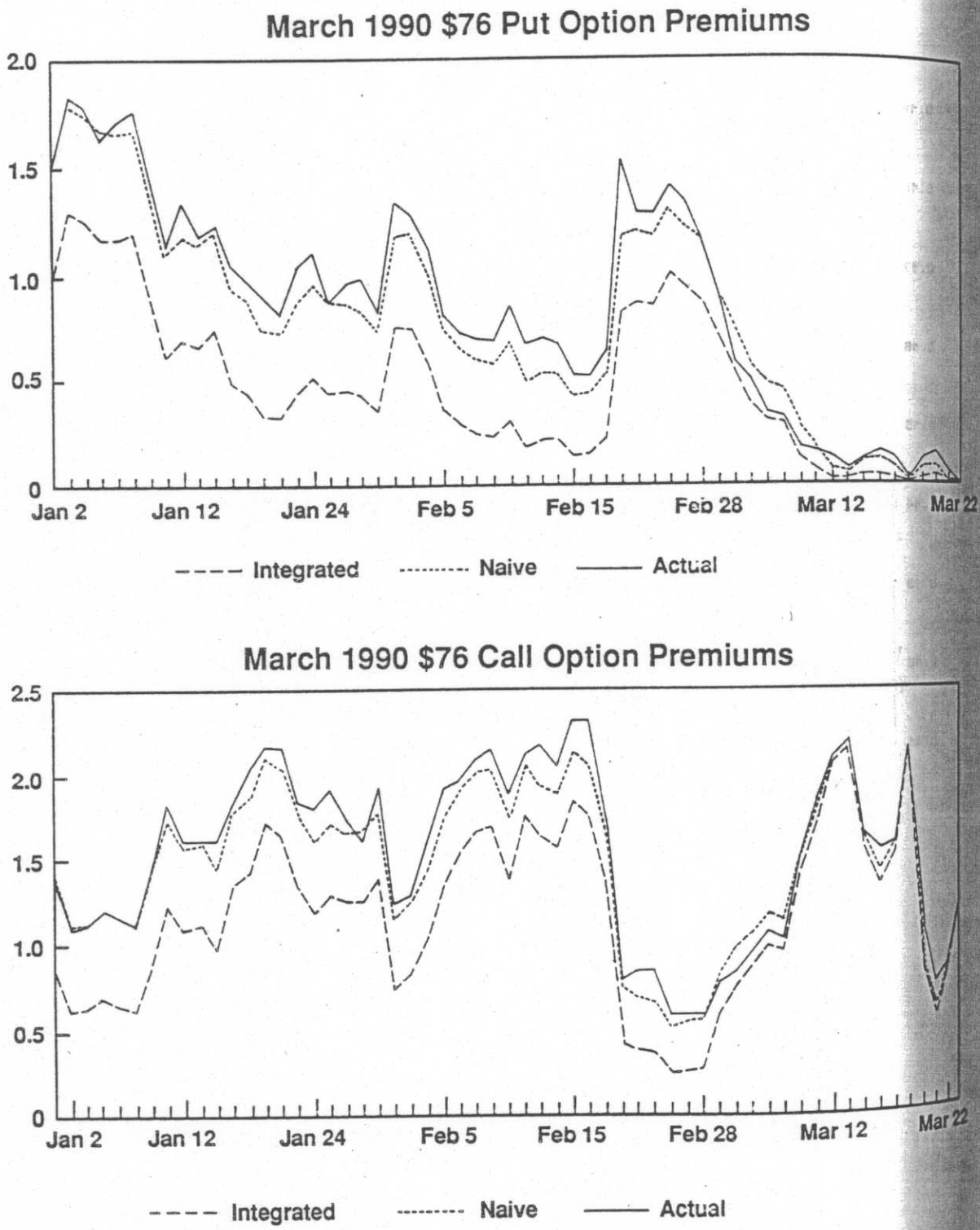


Figure 3. Comparisons of Integrated and Naive Model Forecasts to Actual Option Premiums for an At-the-Money Strike Price with March 1991 Expiration