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Forecasting Futures Price Variability

Joseph W. Glauber and Richard G. Heifner*

Introduction

With the advent of options trading in agricultural commodities much research has focused on how options prices are affected by variability in the underlying futures market[1]. The seminal work of Black and Scholes on the theory of option pricing identified five factors in the valuation of option prices: the exercise price, the time to maturity, the underlying futures price, the risk-free interest rate, and the variability of the underlying futures contract. Plato has shown how option prices are particularly sensitive to the variability of the futures price.

The Black-Scholes option pricing model assumes that the price variability of the underlying contract is constant throughout the life of the contract. Researchers have long questioned, however, whether this assumption is appropriate for agricultural commodities (e.g., Samuelson 1965, 1973, 1976; Anderson and Danthine). Indeed, recent empirical studies have indicated that the volatility of futures prices for agricultural commodities varies seasonally over the life of the contract (Anderson ; Choi and Longstaff; Gordon; Hauser et al.; Kenyon et al.).

To accomodate changing variances, alternative models to the Black-Scholes model have been adapted. The constant elasticity of variance (CEV) model assumes that the variance of the futures prices varies in a constant relationship with the level of price (Cox and Rubinstein). Choi and Longstaff have shown that CEV models tend to give higher (lower) premiums than the Black-Scholes model for both puts and calls when the futures price is lower (equal or higher) than the exercise price. Similarly, using a binomial option pricing model and allowing for early exercise, Gordon and Plato have shown that when the variance is concentrated early in the life of the contract, the value of early exercise for put options deep in the money is greater than when the variance is concentrated in the later periods.

Such research points to the importance of understanding the nature of the variance of futures prices. In this study, a model is presented that examines the determinants of futures price variability. It develops equations to forecast variability based on predetermined economic

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variables representing tightness in supply, interest rates, and seasonality within the marketing year. The work draws on recent developments in the literature on commodity storage on the relationship between stocks and price variability (Gardner; Helmberger and Akinyosoye; Lowry et al.), as well as the recent work by Anderson and Danthine on the relationship between cash and futures prices.

Theoretical Models of Futures Price Variability

Futures price variability has long interested researchers (see Peck; Working). Early theories concerning the variability of futures prices focused primarily on the effects of contract maturity. In an excellent review of this literature, Anderson points out that while many observers recognized a tendency of futures prices to become more volatile as the maturity date of the contract approached, Samuelson (1965, 1973) was the first to develop a formal theory of the maturity effect. Assuming that spot prices follow a stationary, first-order autoregressive process, Samuelson showed that the variance of price changes increased as the delivery date for the commmodity grew nearer. Using a less restrictive martingale model, Samuelson (1976) later demonstrated that for higher-order autoregressive processes the results are somewhat weaker. Under this assumption, it cannot be proven that variances increase monotonically as the maturity date approachs, but one can show that variances of distant price changes tend to be smaller than the variances of price changes near delivery.

While Samuelson maintained that this generalized martingale model was fully compatible with more "fundamentalist" models, Anderson and Danthine demonstrate that such results are highly dependent on the assumption that the variance of the underlying disturbance terms are constant over the life of the contract. Using a multi-period model of simultaneous spot and futures markets, Anderson and Danthine provide an economic interpretation of changes in the variance of futures prices. They show that futures price variability depends on the information that flows into a market. Prices are more variable over periods when large amounts of uncertainty are resolved and are more stable when little new information flows into the market. Thus, price variability does not necessarily increase as the delivery date of the contract approachs.

Anderson and Danthine demonstrate that Samuelson's maturity effect is only a special case of what Anderson terms the state-variable hypothesis. If demand variability is dominant and becomes progressively larger over the life of the contract, the futures price variance will become larger as the delivery date draws near. However, if disturbances are seasonal, as is with the case for many agricultural commodities (e.g., yield uncertainty), the variability of futures prices will vary seasonally as well.

Similar results concerning price variability have been obtained in the commodity storage literature. Using computational rational expectations modeling procedures, Glauber analyzed the effects of planting and carryout decisions on ex ante price expectations and variances held by producers and inventory holders. Results indicate that price variances reflect the size of the underlying disturbance terms of the domestic and export demand and supply equations. As carryout and planted acreage increase ex ante price variances decrease, reflecting the ability of increased supplies to buffer the effect of supply and demand disturbances. Using similar methods, Wright and Williams (1982, 1984) and Lowry et al. have shown how storage costs and interest rates affect ex post measures of expected prices and price variances. They demonstrate how increases in the cost of storage cause inventory holders to store less, thus resulting in increased price variability.

The constant elasticity of variance (CEV) model outlined by Cox (Cox and Rubinstein) proposes that price variability can be explained as a function of the level of the futures price. While it may be argued that price levels and price variability are endogenously determined, if one assumes that exogenous factors affect the two in a roughly proportionate manner, the CEV model may adequately explain changes in price variability. Choi and Longstaff have applied this model to soybeans and found that a positive relation exists between volatility and the futures price level. The magnitude of the elasticity will depend on the relative strength of the exogenous variables on the level of the futures price as compared to the price variance.

The Empirical Model

Modeling price variability presents difficult empirical problems for the researcher. From the theoretical discussion above, it is clear that price variability is affected by the underlying variances of the supply and demand disturbances. Unfortunately, such measures are not readily observable. Previous studies have used binary variables to capture the seasonal effect of these disturbances (Anderson 1980; Hauser et al.; Choi and Longstaff; Kenyon et al.). Such a procedure is followed in this paper as well.

To capture the effect of various economic factors, the following model is estimated:

$$V(P) = a_0 + \sum_{i=1}^{11} a_i D_i + a_{12} FP + a_{13} Int + a_{14} Carry$$

where,

V(P) = the variance of the percent daily change in closing futures prices for contract i during month j; i.e.,
$V(P) = V(\ln(P_t) - \ln(P_{t-1}))$.

D_i = monthly dummy variable (e.g., D_1 = 1 if January; 0 otherwise; December is the base month.)

FP = the average daily future price for contract i during month j (in cents per bushel).

Int = quarterly interest rate for 6 month Treasury bills

Carry = total supply available for consumption in the next quarter (expressed on a monthly basis in 1000 bushels).

All non-binary variables are expressed in natural logarithms; thus, coefficients are interpreted as elasticities.

From the research discussed above, several a priori hypotheses may be drawn concerning the sign of the estimated coefficients. We would hypothesize that the effect of the seasonal variables is greatest over those periods where the greatest amount of uncertainty is resolved. For soybeans, we would expect that uncertainty is greatest in early spring when planting decisions are being resolved and during the summer months when yeilds are determined. An increase in interest rate would cause inventory holders to carry less which would in turn increase price variability. Similarly, an increase in the total supply of soybeans available for next period's consumption would cause futures price variability to decline. Lastly, following Choi and Longstaff, we would hypothesize that futures price variability is positively related to the level of the futures price.

Equations are estimated for six contract months for soybeans (November, January, March, May, July, and September). For storable commodities such as soybeans, futures prices for contracts maturing within the same crop year tend to move together, reflecting the arbitrage relatioships between prices (Working; Tomek and Gray). It is thus expected that factors affecting futures price variability for one contract month will affect price variability of nearby contract months in a similar fashion.

Futures Price Data

Monthly data for futures prices are gathered over the time period January 1961 to June 1984. It is assumed that price changes follow a stationary distribution within a calendar month, but are non-stationary over time periods of greater than one month. Calculating price variances in this manner is admittedly arbitrary. It assumes that the rate of new information into the market does not change during the month. Some authors (Kenyon et al.) suggest the calculation of variance over the period between successive crop reports released monthly by the USDA. However, since markets often react to such information days before the official crop reports are announced publicly (Gardner; Fackler), this choice may be no less arbitrary than calculating variances on a calendar basis.

The average monthly variances of daily price changes for six contract months for soybeans for the period January 1961 to June 1984 are presented in figures 1-6. The graphs have been arranged to show how the variances vary over the last twelve months of each contract[2]. Note that while variances in the maturity month tend to be higher than surrounding months, the data does not generally support the Samuelson hypothesis. For example, the monthly variances for the November contract exhibit a rise during the early spring (March - April) and a larger peak over the summer months (July - August). Not surprisingly, these months correspond to seasons when large amounts of uncertainty is being resolved concerning planting intentions and yields. Note that this seasonal pattern is repeated for all contract months. This suggests that price variances as well as price levels are linked through intraseasonal storage (Tomek and Gray).

Empirical Analysis

Table I presents the estimated regression equations for various contract months over the time sample January 1961 to June 1984. Equations were corrected for first-order autocorrelation using an iterative Cochrane-Orcutt procedure (Johnston). In general, the explanatory power of the equations was higher for contract months at the beginning of the marketing year (e.g., November) than those at the end of the season (e.g., September). Nonetheless, the estimated coefficients of one contract month tend to reflect the sign and magnitude of those of nearby contract months.

As expected, the coefficients for the seasonal variables are largest for July and August. This confirms the earlier observation that price variability is particularly high during these months, and supports similar findings in the literature (Choi and Longstaff; Gordon; Hauser et al.; Kenyon et al.). Note that the estimated coefficients for the delivery month for all contracts are large and statistically significant at the 99 percent level. Paul has recently demonstrated that prices for some commodities show an upwards bias during the last few weeks prior to delivery. These results suggest that price changes during this period may be significantly larger than in other months.

The estimated elasticities for the futures price are positive, of similar magnitude and are statistically significant at the 99 percent level for all contract months. In general, the estimated coefficients for carryout and the interest rate are of the correct sign but not significant, perhaps because these variables are expressed on a quarterly basis and do not capture the monthly variation in the dependent variables.

Note that the coefficient of the autoregressive parameter (AR(1)) is positive and highly significant, suggesting that a high degree of

Figure 1

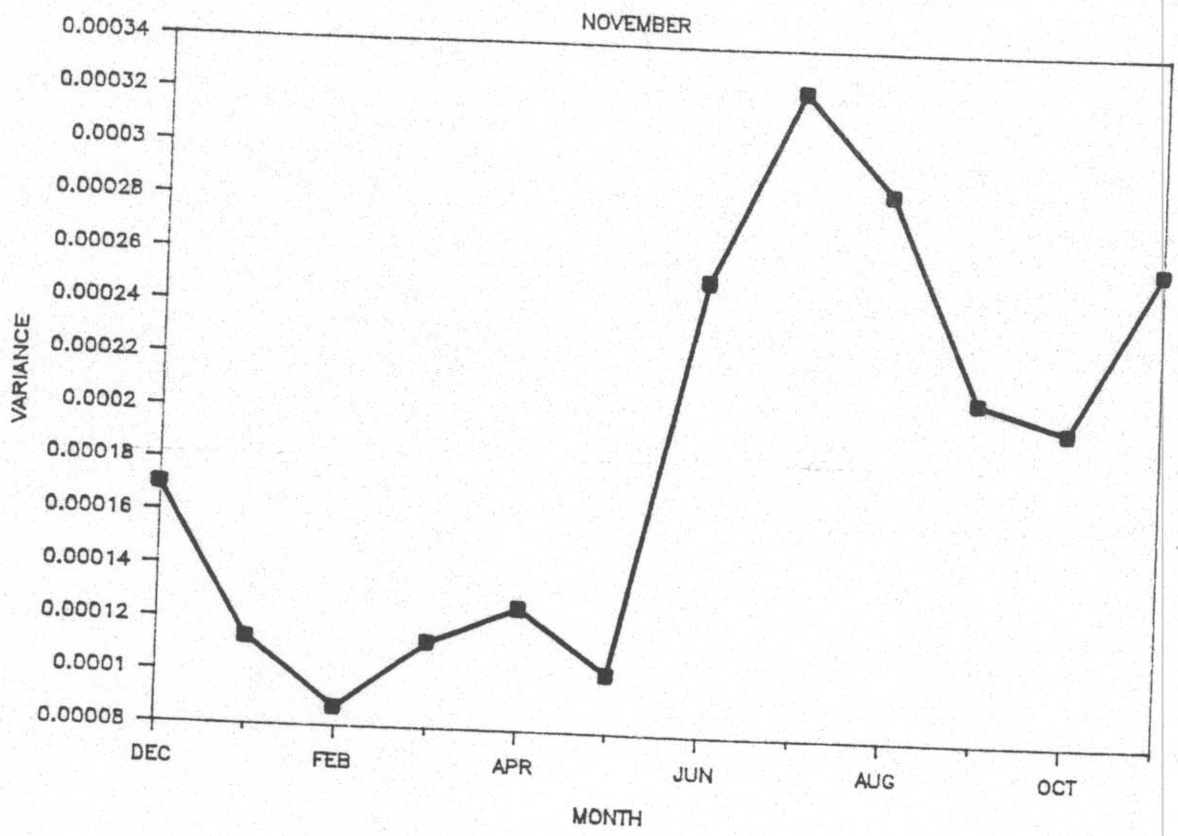

Figure 2

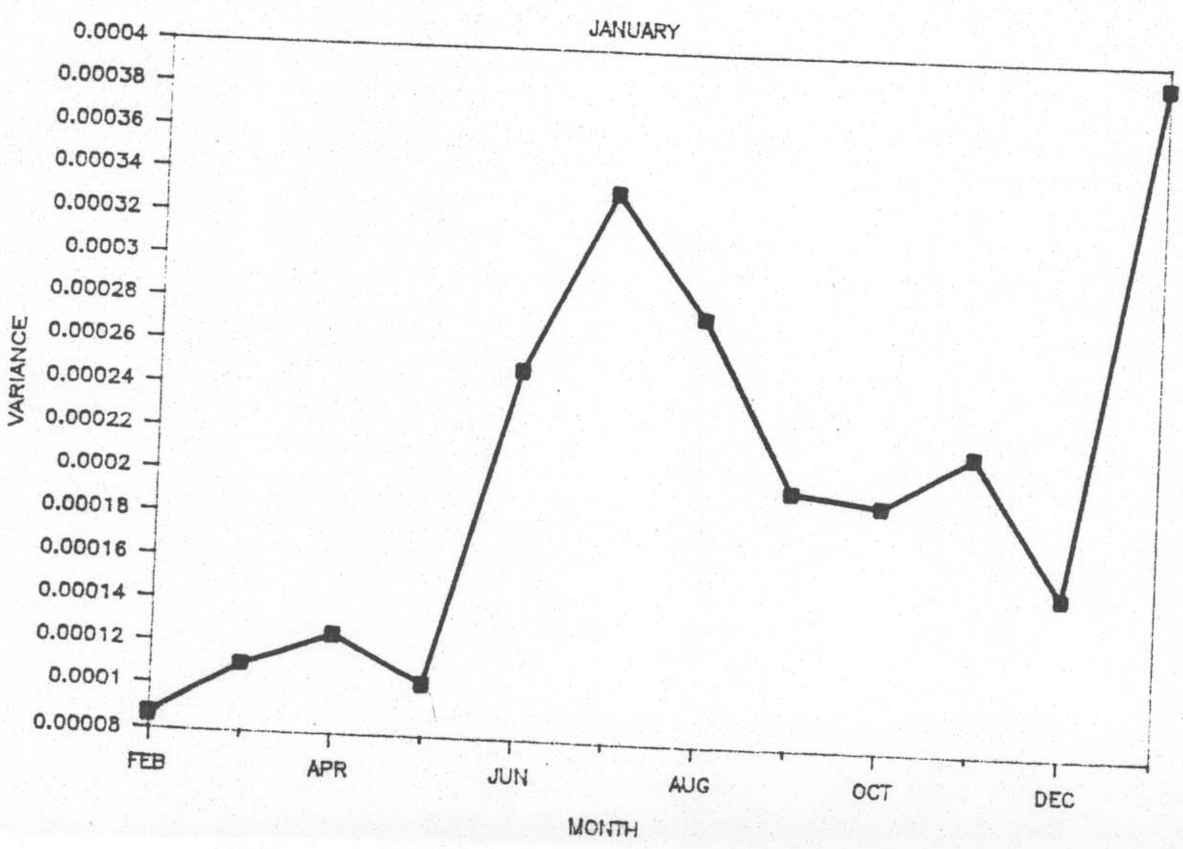

Figure 3

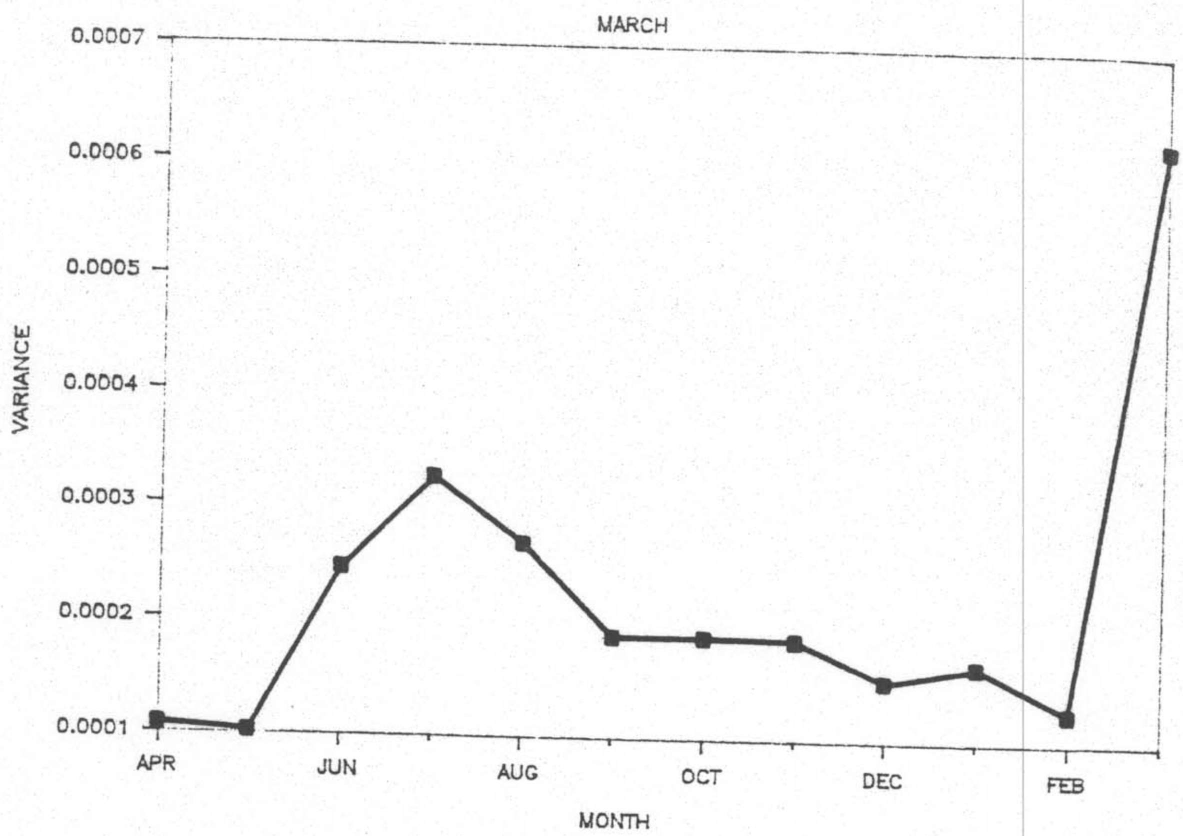

Figure 4

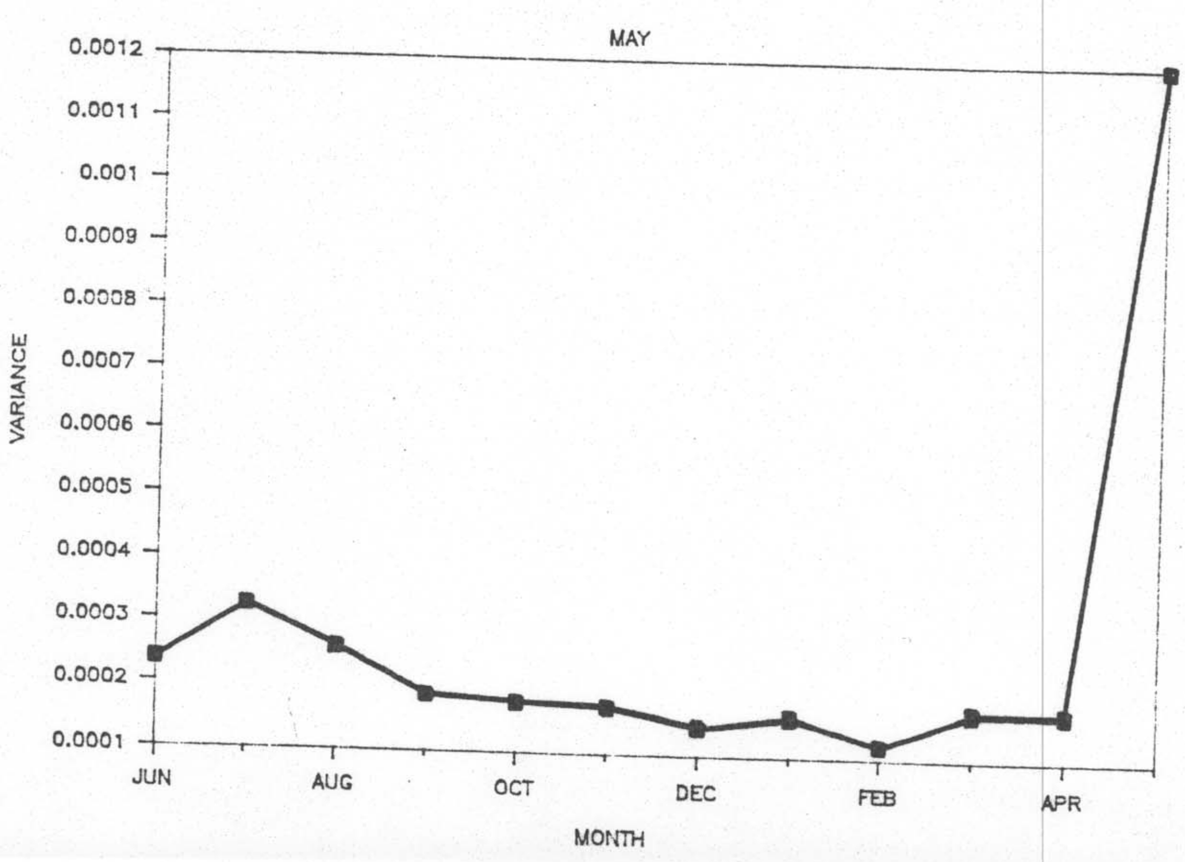

Figure 5

July

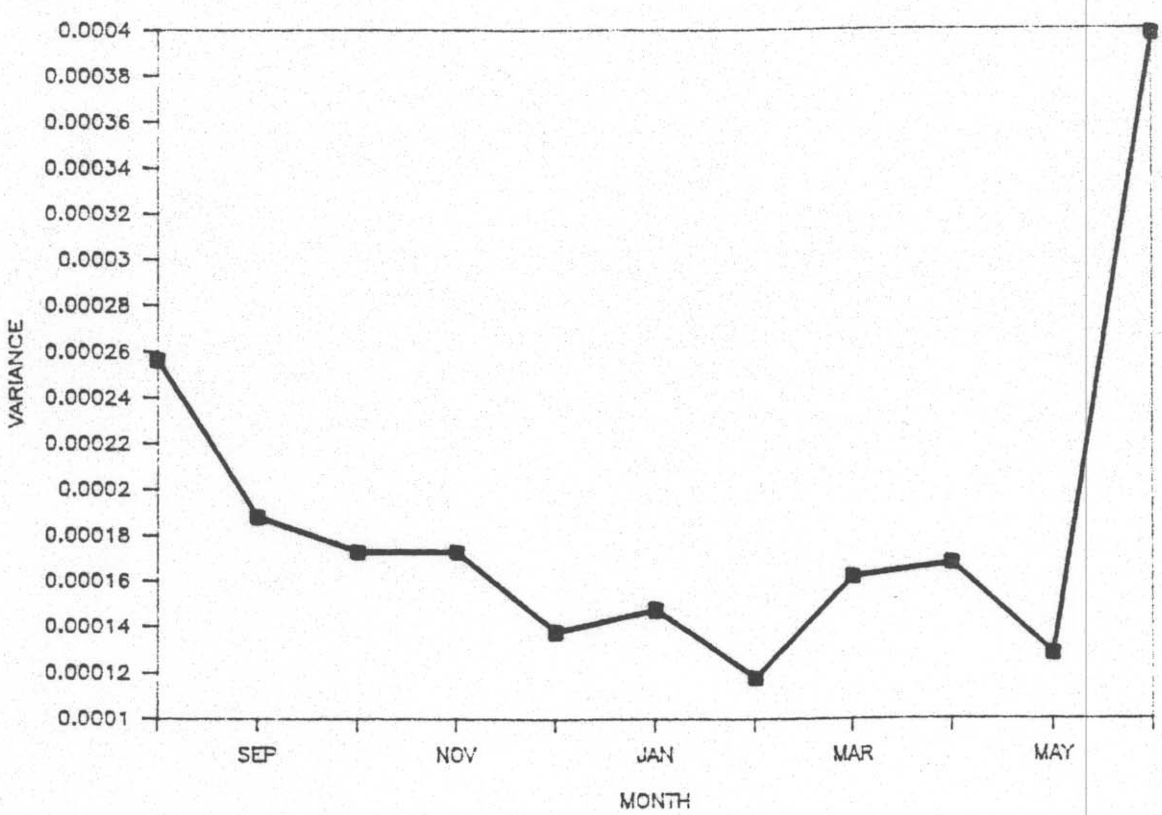

Figure 6

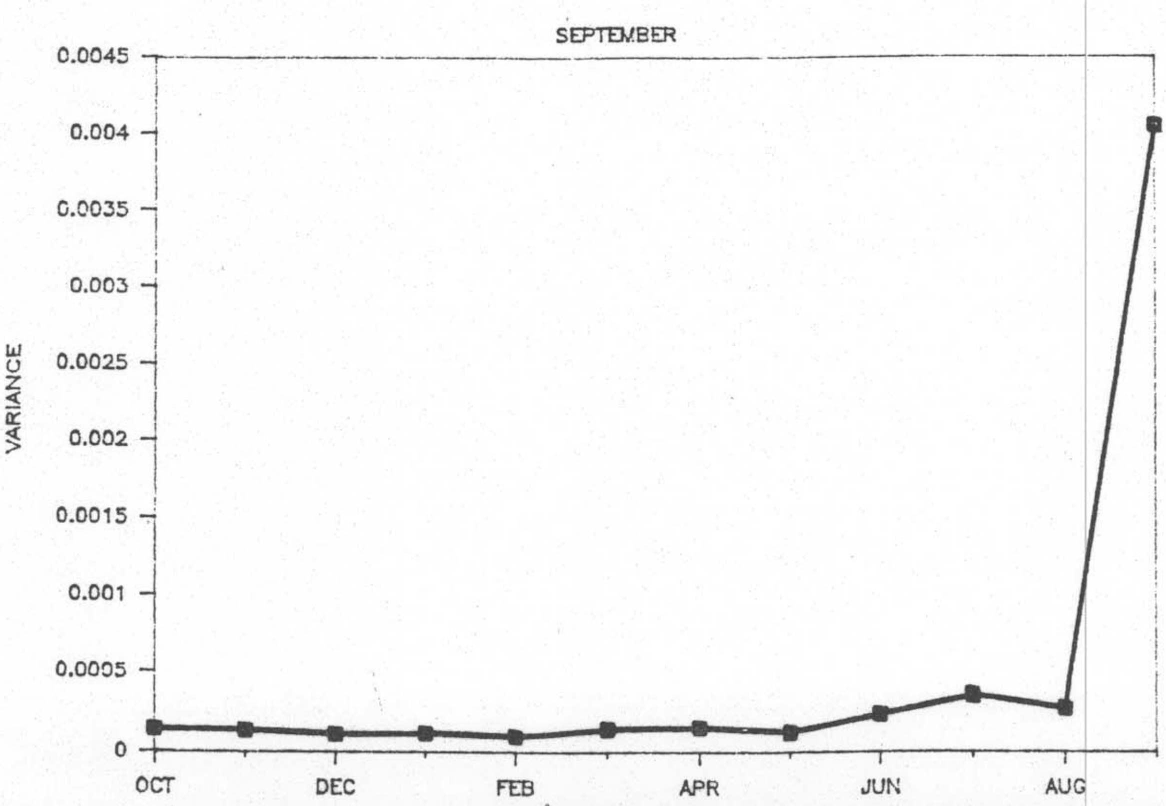

Table I. Estimated regression results for variables affecting monthly variances of daily price changes, 1961-1984. a/

Independent Variables	Contract Month					
	VP11	VP01	VP03	VP05	VP07	VP09
Constant	-15.931	-15.463	-17.008	-17.068	-15.445	-17.408
	(12.775)	(12.035)	(14.444)	(15.926)	(13.273)	(13.134)
D1	.223	.633	.302	.269	.184	.243
	(1.399)	(3.728)	(1.788)	(1.560)	(1.123)	(1.170)
D2	-.254	-.614	-.082	-.154	-.189	-.181
	(1.227)	(2.789)	(.377)	(.694)	(.894)	(.690)
D3	.035	-.356	.598	.095	.014	.110
	(.149)	(1.432)	(2.440)	(.380)	(.061)	(.378)
D4	.172	-.180	-.179	.184	.085	.350
	(.642)	(.635)	(.642)	(.654)	(.314)	(1.073)
D5	.038	-.325	-.232	.571	-.116	.258
	(.136)	(1.115)	(.807)	(1.970)	(.416)	(.774)
D6	.796	.479	.600	.496	.555	.898
	(2.278)	(1.310)	(1.651)	(1.358)	(1.563)	(2.125)
D7	1.124	.790	.905	.857	1.290	1.220
	(3.240)	(2.160)	(2.505)	(2.351)	(3.637)	(2.893)
D8	.956	.567	.698	.585	.425	1.286
	(2.810)	(1.580)	(1.967)	(1.629)	(1.221)	(3.091)
D9	.787	.392	.329	.328	.382	1.374
	(3.369)	(1.591)	(1.347)	(1.332)	(1.612)	(4.756)
D10	.861	.444	.415	.344	.358	.273
	(4.223)	(2.059)	(1.936)	(1.572)	(1.725)	(1.058)
D11	.819	.320	.185	.160	.175	.119
	(5.287)	(1.944)	(1.130)	(.953)	(1.105)	(.590)
FP	4.007	3.910	4.707	4.830	4.008	4.749
	(5.847)	(5.622)	(7.625)	(8.254)	(7.055)	(7.379)
Int	.067	.119	.045	.121	.053	.069
	(.891)	(1.510)	(.572)	(1.534)	(.696)	(1.665)
Carry	-.115	-.106	-.166	-.138	.060	.069
	(1.692)	(1.052)	(1.683)	(1.401)	(.614)	(.749)
AR(1)	.776	.755	.745	.726	.755	.650
	(19.332)	(18.184)	(17.980)	(17.037)	(18.301)	(13.710)
Adj. R^2	.782	.770	.761	.748	.762	.693
d.w.	2.155	2.186	2.288	2.353	2.325	2.279
F	67.587	58.791	60.318	56.343	60.632	43.046

a/ Variables defined in the text. T-ratios are in parentheses.

Table II. Estimated regression results for lagged variance model for various contract months, 1961-1984. a/

Independent Variables	Contract Months					
	VP11	VP01	VP03	VP05	VP07	VP09
Constant	-1.452	-1.757	-1.776	-1.635	-1.631	-2.089
	(4.683)	(5.232)	(5.303)	(5.087)	(5.043)	(5.770)
$V(P)_{-1}$	.847	.813	.811	.825	.825	.779
	(26.385)	(23.244)	(23.081)	(24.307)	(24.169)	(20.612)
Adj. R^2	.715	.659	.656	.679	.676	.603
d.w.	2.331	2.141	2.400	2.512	2.313	2.302
F	696.181	540.273	532.766	590.866	584.142	424.861

a/ T-ratios are in parentheses.

correlation exists between error terms. Table II presents the results of a naive model that estimates the variance of daily price changes as a function of the price variability of the preceding month. The explanatory power of the equations suggests that one could derive reasonable estimates of price variance based on current levels of price variability.

Additional analyses included dividing the data into two subsamples to test whether there was any structural change in the model after the large demand shocks in world markets in the early 1970s. No statistically significant changes in parameters could be shown between the two subsamples. This suggests that changes in the level of the explanatory variable over the sample period explains the change in the level of price variability over the same period.

Conclusions

In this paper we have examined the determinants of futures price variability. We have found that seasonal effects are greatest during the summer months when yield uncertainty is resolved, although there appears to be a significant increase in the level of price variability during the delivery month. Price variability was found to be positively related to the level of the futures price. These results held across all contract months, but the explanatory power of the equations was greatest for those contract months at the beginning of the storage season (November, January and March). Lastly, the explanatory power of the estimated models suggests that these models may be used for forecasting price variability. It is hoped that such forecasts will aid analysts in pricing option premiums.

Footnotes

[1]In this paper, the terms price variance and price variability are used interchangeably to refer to the second moment about the mean of the daily log price change. That is, $V(P) = V(\ln(P_t)-\ln(P_{t-1}))$.

[2]While many contracts are traded 18 months prior to delivery, this study restricts its analysis to the last 12 months of the contract.

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