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Cash Ethanol Cross-Hedging Opportunities

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Abstract

Increased use of alternative fuels and low commodity prices have contributed to the recent expansion of the ethanol industry. As with any competitive industry, there exists some level of output price risk in the form of volatility. Yet, no actively traded ethanol futures market exists to transfer output price risk to. This study reports estimated minimum variance cross-hedge ratios between Michigan spot cash ethanol and the New York Mercantile Exchange (NYMEX) unleaded gasoline futures for 1-, 4-, 8-, 16-, and 24-week hedging periods. The research yields two results. First, the appropriate quantity of ethanol to hedge with one 42,000 NYMEX unleaded gasoline futures contract for each respective hedging period is realized. Second, the magnitude of the quantities of ethanol required to implement an effective minimum variance cross-hedge ratio is recognized as a possible deterrent to ethanol buyers and sellers from entering into a cross-hedge.

Key words: Gas, Ethanol, and Cross-Hedging

Cash Ethanol Cross-Hedging Opportunities

The high demand for fuel and resulting fuel prices have contributed to the recent expansion of the ethanol industry. Ethanol production has increased steadily from 1980, with the exception of a decrease in 1996, to the current record levels (Figure 1). Furthermore the National Corn Growers have publicly stated that their goal is to help grow ethanol production to 16 billion gallons within the next 10 to 15 years. As with any competitive industry, there exists some level of price risk in the form of volatility. Ethanol plant owners, e.g. agricultural producers and private industry, and purchasers of ethanol may benefit from various techniques to manage price volatility. Contractual agreements are widely used in this industry, but even contractual agreements must be negotiated and typically don't cover 100% of ethanol production. Ethanol producers could reduce exposure to price volatility by hedging using corn and gasoline futures markets, i.e., locking in a margin. The Chicago Board of Trade (CBOT) offers a corn futures contract that ethanol producers can use to hedge their corn purchases. For ethanol, however, no futures market is actively traded. Producers and purchasers of ethanol may find cross-hedging ethanol with unleaded gasoline futures contracts to be effective in reducing ethanol production exposure to price volatility. The objective of this study is to estimate the cross-hedge relationship between spot ethanol and New York Mercantile Exchange (NYMEX) unleaded gasoline futures market for various cross-hedging horizons.

In order for cross-hedging to reduce price risk, the prices of the commodities being cross-hedged must be related, so that the respective prices follow in a predictable manner (Graff et al.). Figure 2 graphically depicts the Detroit spot ethanol price and the nearby NYMEX unleaded gasoline futures contract price. These markets have traded in similar patterns, but at different levels, over the previous thirteen years. The standard deviation about the average price of spot ethanol is $0.17/gallon, and the standard deviation about the average price of any gasoline futures contract, over the contract life, is on average around $0.105/gallon. The standard deviation of the spot ethanol cash price is greater than the standard deviation of the nearby unleaded gasoline futures price by 62%. Thus, there is some antidotal evidence that routine cross-hedging could mitigate spot ethanol price volatility.

Increased expansion in the ethanol industry is likely to heighten the demand for price risk management tools. Contracting in cash markets, alone, may leave ethanol producers and purchasers subject to price risk exposure from ethanol price volatility, depending on contract terms. Processors and purchasers of ethanol can use this research to understand the effectiveness of cross-hedging cash ethanol in the unleaded gasoline futures market to mitigate price risk. Furthermore, inferences are made regarding the creation of a stand alone ethanol futures contract.

Theoretical Background

The theoretical model used to derive the empirical cross-hedge model follows from Brorsen, Buck, and Koontz and Luthold, Junkus, and Gordier. Brorsen, Buck, and Koontz (p. 451) show that under the assumptions (set forth by Benninga, Eldoer, and Zilcha) of, ". . . (i) the decision maker is not allowed to participate in alternative activities, (ii) no transaction costs, (iii) no production risk, (iv) cash prices are a linear function of futures prices with an independent error term, and (v) futures prices are unbiased," the mean-variance utility maximization problem can be specified as:

(1) $$MaxE(U) = X_c E(\tilde{R}_c) + X_f E(\hat{R}_f) - \lambda / 2(X_c^2 \sigma_c^2 + X_f^2 \sigma_f^2 + 2 X_f X_c \sigma_{cf}) \ ,$$

where E(U) is the expected utility, X_c is the amount of the cash price position, $E(\tilde{R}_c)$ is the expected return on the cash position, X_f is the amount of the futures price position, $E(\tilde{R}_f)$ is the expected return on the futures position, λ is the relative risk aversion coefficient, σ_c^2 is the variance of the cash price change, σ_f^2 is the variance of the futures price change, and σ_{cf} is the covariance between the change in cash and futures prices.

Expressing equation (1) in terms of price differences, differentiating with respect to X_f and rearranging terms yields the optimal futures position, adjusted for risk aversion of the form:

(2) $$X_f = \{E(\tilde{F}_1) - F_0)] / \lambda \sigma_f^2\} - [X_c (\sigma_{cf} / \sigma_f^2)] \ ,$$

where $E(\tilde{F}_1)$ is the expected futures price at time 1, F_0 is the futures price at time 0, and σ_{cf} / σ_f^2 is the cross-hedge relationship.

Empirical analyses to determine cross-hedging ratios have been carried out extensively for agricultural commodities, e.g. Buhr; Graff et al.; Hayenga and DiPietre; Rahman, Turner, and Costa; Schroeder and Mintert. Anderson and Danthine provided a theoretical cross-hedging model from which most empirical analyses are based, and some authors (e.g., Brorsen, Buck, and Koontz) have estimated optimal hedge ratios dependent upon the hedgers risk aversion level as specified in equation (2). However, Kahl has shown that when the spot and futures prices are endogenous the optimal hedge ratio does not depend on the hedger's risk aversion level. Therefore, the cross-hedge ratio in the current study is estimated without consideration to the risk aversion level of the hedger. Under this pretense, the first term of equation (2) is zero, and the cross-hedge ratio is:

(3) $$\beta^* = \frac{X_f^*}{-X_c} = \frac{\sigma_{cf}}{\sigma_f^2} \quad ,$$

The cross-hedge ratio in equation (3) can be determined by estimating the *ex post* hedging efficiency model following (Leuthold, Junkus, and Cordier):

(4) $$(Cash_t - Cash_{t-k}) = \beta_0 + \beta_1(Unleaded\ Gas\ Futures_t - Unleaded\ Gas\ Futures_{t-k}) + \varepsilon_t \ ,$$

where the change in cash and futures prices for the relative hedging period is the difference between *t*-*k* and *t*. The cross-hedge ratio estimated from equation (4) represents the minimum variance cross-hedge ratio (Leuthold, Junkus, and Cordier). The next section describes the process of estimating the cross-hedge coefficient.

Empirical Model

A cross-hedge is performed by hedging the cash price of a commodity with the futures contract price of a different, but related commodity. A hedger locks in the price for a commodity offered on the cash market, by cross-hedging that commodity with another commodity in the futures market. In other words, a cross-hedge utilizes information in one market, i.e., the futures market, to predict the price of a different commodity in another market, i.e. the spot market. The conventional practice of hedging gasoline in gasoline futures markets is to use one 42,000 gallon contract for each 42,000 gallons of gasoline to be hedged. However, since ethanol is not a perfect substitute for gasoline the one-to-one ratio may be inappropriate. Thus, the calculation of a cross-hedge ratio is necessary to determine the size of the futures position to take.

Time-series data, such as the type used to calculate the cross-hedge ratio, is likely to exhibit autocorrelation and time-wise heteroskedasticity. A moving average process equal to the length of the hedge period may be present. Thus, 1^{st} and k^{th} order autocorrelation is corrected for in the estimation of the cross–hedge ratio. Approximating the moving average as an autoregressive process with lags of one and k corrects for autocorrelation. The autoregressive process is selected for its extensive properties, correcting for autocorrelation from overlapping data, as well as from other sources (Brorsen, Buck, and Koontz). Following the work of Brorsen, Buck, and Koontz for cross-hedging wheat, the relationship between cash prices for ethanol and unleaded gasoline futures prices is estimated in changes to determine the cross-hedge ratio (β_1) from equation (5):

$$\begin{aligned}
(5)\qquad & \Delta \textit{Ethanol Cash Price}_t = \beta_0 + \beta_1 (\Delta \textit{Futures Price}_t) \\
& \quad + \rho_1 [\Delta \textit{Ethanol Cash Price}_{t-1} - \beta_0 + \beta_1 (\Delta \textit{Futures Price}_{t-1})] \\
& \quad + \rho_k [\Delta \textit{Ethanol Cash Price}_{t-k} - \beta_0 + \beta_1 (\Delta \textit{Futures Price}_{t-k})] ,
\end{aligned}$$

where Δ *Ethanol Cash Price*$_t$ is the difference in the ethanol cash price over the period *t-k* to *t*; Δ *Futures Price*$_t$ is the difference in the Nearby NYMEX unleaded futures price over the hedge period to *t-k* to *t*; Δ *Ethanol Cash Price*$_{t-1}$ is the Δ *Ethanol Cash Price*$_t$ lagged one period; Δ *Futures Price*$_{t-1}$ is the Δ *Futures Price*$_t$ lagged one period; Δ *Ethanol Cash Price*$_{t-k}$ is the Δ

Ethanol Cash Price$_t$ lagged *k* periods; ☛ *Futures Price*$_{t-k}$ is the ☛ *Futures Price*$_t$ lagged *k* periods; ρ_1 is the first-order autocorrelation parameter; ρ_k is the k^{th}-order autocorrelation parameter; (β_0) is the intercept; and (β_1) is the minimum variance cross-hedge coefficient. For this study the cross-hedging periods analyzed (denoted by ☛) are 1-, 4-, 8-, 16-, and 24-weeks.

Another potential problem, heteroskedasticity in the error terms, may result from the cyclical periods of high and low volatility in the unleaded gasoline futures contract. A generalized autoregressive conditionally heteroskedastic (GARCH) process is implemented to correct for the presence of heteroskedasticity.

Following the methodology of Brorsen, Buck, and Koontz a Estimated Generalized Least Squares (EGLS) process is used to correct for autocorrelation first and heteroskedasticity second, since GARCH parameter estimates are not consistent in the presence of autocorrelation. First, non-linear least squares are used to estimate equation (5). Second, a GARCH (1,1) model is used to derive the residuals of the nonlinear least squares estimate of equation (5). Last, equation (5) is estimated using weighted non-linear least squares. The three-step EGLS process is calculated using *SHAZAM* 9.0.[1]

Equation (5) can be rearranged to determine the quantity of cash ethanol to hedge per NYMEX unleaded gasoline futures contract. The cross-hedge relationship from equation (5) is used, in conjunction with the NYMEX contract quantity specification of 42,000 gallons, to determine the approximate gallons of ethanol to hedge, such that

$$(6) \qquad \textit{Cash Quantity Hedged} = \frac{\textit{Futures Contract Quantity}}{\beta_1} .$$

[1] Note, adjusting the data and residuals to compensate for the presence of autocorrelation and heteroskedasticity yield parameter estimates similar to the OLS estimated parameters, but with efficient standard errors.

The *Futures Contract Quantity* is the gallon amount per unleaded gasoline futures contract, and the *Cash Quantity Hedged* is the gallons of ethanol hedged per futures contract. For example, one 42,000 gallon gasoline contract on the NYMEX would be appropriately cross-hedged against 42,000 gallons of ethanol if the cross-hedge ratio (β_1) is determined to be 1.0. Similarly, if the cross-hedge ratio was estimated to be 0.80, the appropriate number of gallons to cross-hedge against one NYMEX unleaded gasoline futures contract is 52,500 gallons (= 42,000/0.80).

Data

Weekly average price data for NYMEX unleaded gasoline futures contracts and weekly average Detroit spot ethanol prices were compiled as a time series from January 1, 1989 to November 29, 2001. Changes in futures prices over the cross-hedging period were computed for the representative contract month for when the hedge is to be lifted. For instance, if the cross-hedge is to be lifted during any week in February 2001, then the change in the futures price over the 1-, 4-, 8-, 16-, and 24-week period is in reference to the March 2001 contract. NYMEX unleaded gasoline futures prices were obtained from the Commodity Research Bureau. The Detroit ethanol spot price data were obtained from Kappell. Summary statistics are listed in Table 1. Summary statistics for the NYMEX unleaded gas futures price is for the nearby contract only.

Ethanol ranged from a maximum price of $1.77/gallon, to a minimum price of $0.95/gallon and averaged $1.19/gallon. The standard deviation about the average price of ethanol is $0.17/gallon, resulting in a 0.15 coefficient of variation. The nearby price of NYMEX unleaded gasoline futures ranged from a minimum of $0.29/gallon to a maximum of $1.14/gallon. The NYMEX unleaded gasoline futures contract averaged $0.60/gallon.

Results

As previously mentioned, the time-series data used for this study could exhibit statistical issues, i.e. autocorrelation and heteroskedasticity. The EGLS process is used to correct for autocorrelation, approximating the moving average as an autoregressive process using nonlinear least squares, and to correct for heteroskedasticity using an ARCH process and weighted nonlinear least squares. After transforming the data for 1^{st} and k^{th} order autocorrelation through non-linear estimation of equation (5), an autoregressive conditional heteroskedasticity test of the errors was performed. The ARCH test statistic is computed as $N \bullet R^2$, where N=653 and the R^2 is from regressing the squared lagged one period autoregressive corrected residuals on the current period squared autoregressive corrected residuals. Table 2 summarizes the computed test statistics for homoskedasticity. For the 24-week cross-hedging period, the null hypothesis of homoskedasticity was rejected. Thus, all but the 24-week model were corrected for conditional autoregressive heteroskedasticity.

The autocorrelation coefficients, constants and the estimated cross-hedge relationships from equation (5) are presented in Table 3. The autocorrelation parameter estimates are significant for each of hedging periods, indicating the strong presence of autocorrelation.

The *R-squared* statistics reported for the change in price models are a measure of hedging effectiveness. Leuthold, Junkus, and Cordier (p. 94) state, ". . ., hedging effectiveness refers to the reduction in variance as a proportion of total variance that results form maintaining a hedged position rather than an unhedged position." The *R-squared* terms become progressively better for further out forecasts. The R-*squared* on the 1-week cross-hedge period, however, indicates relatively little hedging effectiveness. Thus, a hedger would be as well off to remain unhedged for such a short time period.

The cross-hedge coefficients are less than one and are statistically significant at the 1% level for each of the 1-, 4-, 8-, 16-, and 24-week periods. The appropriate quantities of ethanol to be hedged against one 42,000 gallon unleaded gasoline futures contract for each hedging period are calculated by applying the cross-hedge coefficients to equation (6), and are listed in gallons across the bottom of Table 3. The quantity of spot ethanol to hedge declines substantially as the hedging period increases. Though these values appear relatively large compared to the NYMEX unleaded gasoline futures contract of 42,000 gallons, a 30 million gallon per year ethanol plant would require 149 contracts to cover a 4-week routine hedge and 297 contracts to cover a 24-week routine hedge. Furthermore, for the ethanol industry over 8,000 and 16,000 NYMEX unleaded gasoline futures contracts would be required annually to routinely hedge a 4-week and a 24-week cycle, respectively. Hedging 100% of production in this industry is not a likely alternative, but as the ethanol industry expands, there will be increased interest to mitigate price volatility.

Discussion

Ethanol production has reached record levels, becoming a substantial source of corn demand with potential for and expectations of further growth. The lack of an actively traded ethanol futures market limits ethanol plant managers' options to mitigate price risk. Ethanol and gasoline prices are relatively volatile and appear to follow similar patterns at different levels, suggesting that a cross-hedge has potential to mitigate price risk.

For our analysis, we estimated a cross-hedge relationship between the spot ethanol price and NYMEX unleaded gasoline futures price. Using Estimated Generalized Least Squares to account for autocorrelation and heteroskedasticity, cross-hedge ratios for 1-, 4-, 8-, 16-, and 24-week periods were estimated. The cross-hedge ratios varied from 0.175 for the 1-week, to 0.418 for the 24-week hedging period. The measure of hedging effectiveness (R^2) indicated that placing a cross-hedge could substantially mitigate price volatility for the 4-, 8-, 16-, and 24-week periods. Additionally, the hedging effectiveness increased for longer cross-hedging periods.

Two results yield from this analysis. First, the quantity of spot ethanol to cross-hedge was estimated to be 193,548 gallons, 152,727 gallons, 146,853 gallons, and 100,478 gallons for the 4-, 8-, 16-, and 24-week hedging periods, respectively. Thus, considerably more gallons of ethanol are required to cross-hedge effectively than when hedging one-to-one with the 42,000 gallons of unleaded gasoline specified for the NYMEX unleaded gasoline futures contract. Second, the quantities required to implement an effective cross-hedge ratio may be cause of reluctance by some buyers and sellers to enter into a cross-hedge. Current capacity in the ethanol industry is far too small to sustain an independent ethanol futures contract. However, as the ethanol industry expands the relevance of an ethanol futures contract may increase substantially.

The limitation of this study is obvious. This study is limited to one location because of the costs of acquiring spot ethanol price series from multiple locations. Thus, the cross-hedge ratios, and thereby, the optimal quantity of spot ethanol to hedge, could vary by location.

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Figure 1. US Annual Fuel Ethanol Production (Energy Information Administration and Renewable Fuels Association).

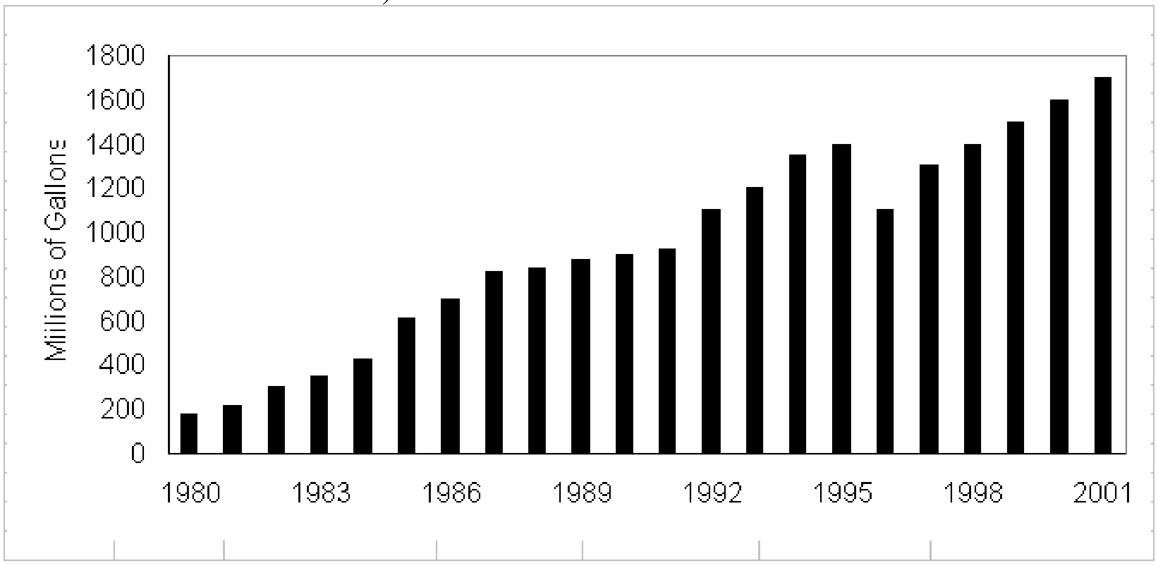

Figure 2. Michigan Spot Ethanol Price and NYMEX Unleaded Gasoline Futures Price.

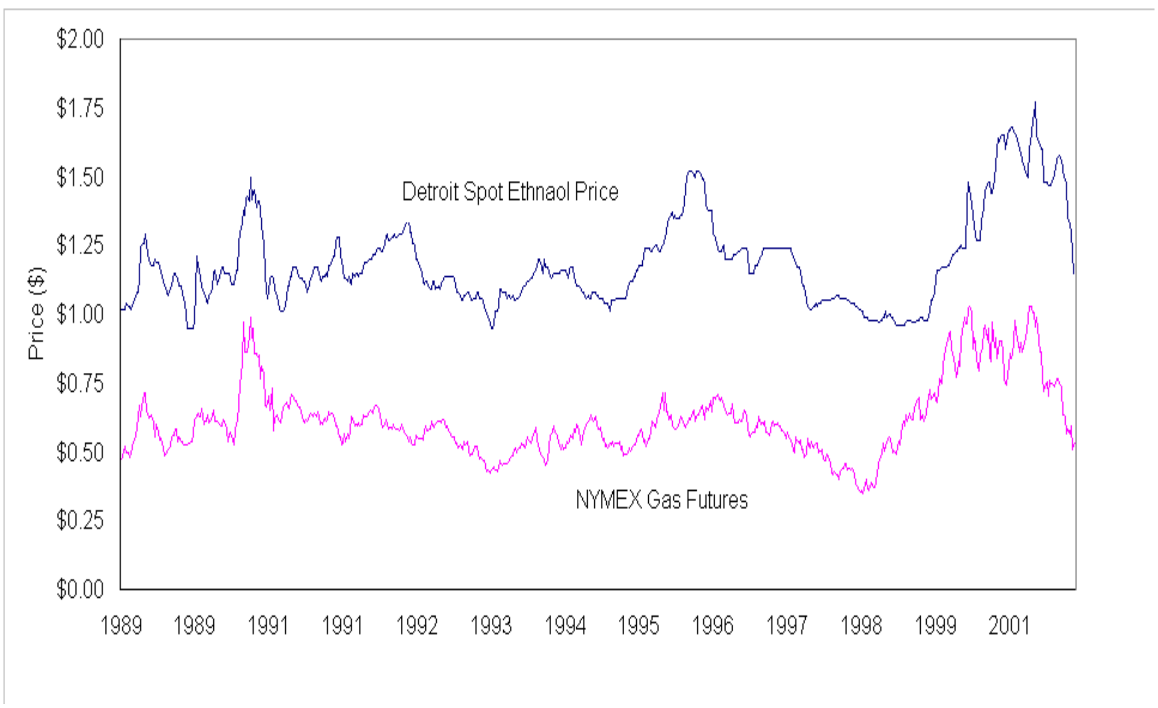

Table 1. Summary Statistics for Variables Used in Estimation of Cross-Hedging Ethanol in Gasoline Futures, January 1, 1989 to November 29, 2001.

Prices in \$/gallon	Avg.	Std Dev	Min.	Max.
Nearby NYMEX unleaded gas futures	0.60	0.15	0.29	1.14
Detroit spot ethanol	1.19	0.17	0.95	1.77

Table 2. Summary Statistics of Statistical Test for Heteroskedasticity.

	Weeks Cross-hedge Held				
	1-week	4-week	8-week	16-week	24-week
Test statistic (Ho: errors are homoskedastistic)	5.555***	74.447***	21.65***	144.057***	0
(p-value)	(0.018)	(< 0.01)	(< 0.01)	(< 0.01)	(0.997)

Note: Test statistics (NR^2) based on regression estimated as: $e_t^2 = \alpha_o + \alpha_1 e_{t-1}^2 + \lambda_t$, based on 653 observations from the autocorrelated corrected data. Three asterisks (***) indicate statistically significant at the 0.01 level.

Table 3. Estimated Cross-Hedge Relationships from Equation (1).

	Weeks Cross-hedge Held				
	1-week	4-week	8-week	16-week	24-week
Constant (β_0)	-0.001	-0.004	-0.005	-0.012	-0.030***
	(0.001)	(0.004)	(0.008)	(0.018)	(0.001)
Cross-hedge coefficient (β_1)	0.175***	0.217***	0.275***	0.286***	0.418***
	(0.037)	(0.029)	(0.041)	(0.043)	(0.005)
1^{st}-Order autocorrelation (ρ_1)	0.185***	0.93***	0.924***	0.966***	0.995***
	(0.039)	(0.021)	(0.016)	(0.012)	(0.003)
k^{th}-Order autocorrelation (ρ_n)	NA	-0.221***	-0.090***	-0.044***	0.008***
	NA	(0.022)	(0.017)	(0.009)	(0.003)
R-*squared* (R^2)	0.091	0.784	0.874	0.931	0.984
Number of observations	653	653	653	653	653
H_o: $\beta_1 = 1$ (*p*-value reported)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Quantity of ethanol per 42,000 gallon unleaded gasoline futures contract (gallons)	240,000	193,548	152,727	146,853	100,478

Note: 24-week model not corrected for conditional heteroskedasticity. Standard errors are reported in parentheses. Three asterisks (***) indicate statistically significant at the 0.01 level.