An Exploration of Market Pricing Efficiency:

The Dairy Options Pilot Program*

David Buschena and Kevin McNew **

Introduction

Put options have been recommended as a substitute for price support programs (Gardner 1977; also some more recent comments?), and subsidized option purchases have received some support in lieu of subsidized insurance programs (cite?). Put options are an interesting alternative to price supports because their market-determined price levels allow for flexibility and adjustments to relevant current and expected market conditions. Options markets should also be relatively free from the bureaucratic decision processes needed for administration of commodity price supports.

Put options as a substitute for commodity price supports have some unattractive features, however. From a producer's perspective, put options can smooth short- to medium-term price movements but for many commodities options cannot be purchased more than one crop year in the future. This limited time horizon for options purchases means that longer-term price variability due to supply and demand changes, or both, cannot be reduced effectively through the use of put options.

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** The authors are Associate Professors in the Department of Agricultural Economcis and Economcis, Montana State University, Bozeman, MT. We benefited greatly from conversations with Monte Vandeveer and Lee Ziegler. Funding for this research was provided by USDA-ERS and by the Montana Agricultural Experiment Station. Wei Wu provided research support for this project.

Another drawback to using put options as a substitute for commodity price supports is the relative thinness of these markets for some commodities. Market thinness is defined here as the absence of traders willing to take the necessary opposite position in the market in lieu of a relatively large price premium. Market thinness is difficult to measure and varies considerably across commodity options contracts. For example, a buyer of 1, 10, or even 100 near the money put options for the upcoming November delivery of soybeans on the Chicago Board of Trade will likely be able to have any of these buy orders filled within a few minutes at a price at or very close to the immediately previous trade. In contrast, a buyer of 1, or 10 (to say nothing of 100) put options for November delivery of canola on the Winnipeg Commodity Exchange may wait many minutes or even hours for their order to be filled.

We explore empirically how a thin market responds when trading increases as a result of a subsidized put option program. USDA initiated the Dairy Options Pilot Program (DOPP) in 1999 in an effort to provide dairy producers with real-world experiences trading options. Subsequently, additional rounds of DOPP occurred to give more producers a chance to participate. In total, over 1,300 producers bought 6,500 milk put option contracts through the DOPP program from 1999 to 2002. In contrast, over this four-year period total put options traded at the Chicago Mercantile Exchange (CME) milk futures market totaled over 36,000 contracts. Thus, the volume from the DOPP program represented a fairly large share of total trading activity in the dairy put options market.

This case study of subsidized fluid milk options provides some useful features for the evaluation of how subsidized options purchases affects options markets. First, the fluid milk options market has relatively low volume (Figure 1), but trading volume has increased over time — from 190 contracts per day on average in 1999 to over 400 contracts per day on average by 2002. Nonetheless, trading volume in milk futures and options remains well below that for other agricultural commodities. For example, in 2002 average daily trading volume for the CME's Live Cattle futures market was over 15,000 contracts per day while the smaller Pork Belly futures market at the CME averaged 725 contracts per day.

A second interesting feature of the subsidized milk options program is that dairy farmers may have made relatively little use of commodities markets due to the long-standing dairy price support programs. If this is the case, many of the dairy farmers making use of this subsidized options purchase program would have been relatively uniformed traders. Although DOPP may have increased trading volume, market performance may or may not have been enhanced due to the relative unfamiliarity with options trading by these dairy producers.

Policy and Market Setting

Farm Programs.

Farm level milk prices have been supported under some type of federal price support program for more than 70 years (Cropp). Although efforts have been made to reduce these price supports in the late 1980s (The Food Security Act of 1985) and in the 1990s (The Food, Agriculture, Conservation, and Trade Act of 1990 and the Federal Agriculture Improvement and Reform Act of 1996), effective price support programs for fluid milk returned in the Farm Security and Rural Investment Act of 2002. Because effective price supports are thought to reduce producer interest in hedging, there was likely to be little producer interest in fluid milk futures or options markets prior to the price support reforms in the late 1980s and 1990s. Vandeveer, et al. provides a very detailed description of historical dairy production, the dairy processing industry, and government dairy policy in the United States.

Dairy Futures and Options Markets

In December of 1995, fluid milk futures and options contracts were launched at the New York Board of Trade (NYBOT), joining cheddar cheese and nonfat dry milk futures and corresponding options contracts initially listed for trading at the NYBOT in June 1993. Futures and options contracts for butter on the NYBOT began trading in mid-October 1996. In addition to the NYBOT, the CME began trading fluid milk contracts in January 1996.

The milk futures contracts on both exchanges initially used the USDA's Basic Formula Price[1] (BFP). Contract size was 100,000 lbs. BFP milk at the NYBOT and 200,000 lbs. at the CME, respectively. The USDA announced a new Class III formula in January 2000 that replaced the BFP formula in response to the new component pricing structure for milk used for manufacturing hard cheese. In response to this definitional change by the USDA, both exchanges changed their contract specifications to Class III milk, with other contract details remaining unchanged. The CME added a Class IV contract in July 2000 in response to industry interest in a contract more closely related to butterfat price risk.

Milk futures and options trading were terminated on the NYBOT in June 2000 in response to low trading volumes. The CME continues to trade Class III and Class IV fluid milk futures and options, with some growth evident in trading volume for both futures and options markets (Figure I).

The Dairy Options Pilot Program (DOPP)

[1] An estimate, calculated and announced by the USDA, of the average price paid for Grade B (manufacturing) milk by plants in Minnesota and Wisconsin adjusted for contemporaneous changes in the prices of manufactured milk products.

DOPP was developed by the USDA's Risk Management Agency in collaboration the NYBOT, the CME, the USDA's Economic Research Service, and the Commodity Futures Trading Commission, with a notice of availability published for DOPP in November 1998. The development of the program represented an effort to address the increasing dairy price volatility that arose from the reduction in real government price supports in the late 1980s and 1990s (Figure 2).

DOPP was designed to teach producers how fluid milk put options can be used to provide price protection. The USDA cost-share arrangement subsidized the purchase of these put options, paying 80% of the put option's price and up to $30 in commission fees. These and other pilot programs were permitted under Section 191 of the Federal Agriculture Improvement and Reform Act of 1996. Producers participating in DOPP were required to attend an options training program, and were limited to purchasing puts that were at least 10 cents out of the money.[2] These producers could qualify for DOPP minimum volume levels with even with a small number of cows, and could participate in multiple rounds (Vandeveer, et al.). DOPP had four rounds:

Round 1 began in January 1999, available in 38 counties in 7 states;

Round 2 began in January 2000, available in 61 counties in 32 States;

Round 3 began in January 2001, available in 275 counties in 39 states;

Round 4 trading began in May 2002, available in 300 counties in 40 states.

The evaluation by Vandeveer, et al. (2003) offers a complete description of the origin of DOPP and its administration.

Producers had put options purchase minimums of 100,000 lbs. of milk in a round, but could not exceed 600,000 lbs. of DOPP put options during a year, nor more than 200,000 lbs.

[2] A put option is out of (in the) money if its strike price is less (greater) than the corresponding futures price.

in any given month (Vandeveer, et al.). The minimum requirement would not have been binding for virtually all commercial milk producers, while the maximum requirement would have been binding for many producers. The options purchased under DOPP had to have at least two months but not more than twelve months remaining before expiration at the time of purchase. The producer was required under DOPP to hold the options until within one month of expiration, after which the producer could exercise the option, sell the put, or allow it to expire. This requirement to hold the option until at most one month remains until expiration would decrease the value of the option to the producer relative to the value of the option if it were not purchased through DOPP. The extent of this reduction in value is difficult to determine given available market data for the fluid milk options market.

More than 6,000 dairy producers participated in DOPP during its four rounds, comprising somewhat over 5% of total U.S. dairy farms (Vandeveer, et al.). As will be shown in our empirical section, DOPP trades significantly increased trading activity in the dairy put markets, which is reflected by the increase in the average daily market volume and open interest.[3] Additionally, overall option market pricing efficiency appears to have improved with the increased market volume stemming from the DOPP subsidized purchases.

The milk call options market, a counterpart to the puts, provides another test for the effects of on options pricing efficiency. The expectedly close price relationships between put options, call options, and futures markets for fluid milk due to arbitrage possibilities (Hull 2001; Campbell, Lo, and MacKinlay 1997) allow us to test the differential effects of subsidized put options purchases through DOPP on related options markets.

[3] The number of outstanding contracts.

Measuring Market Performance

Market Liquidity

Liquidity is defined as the ability to buy or sell significant quantities of a security quickly, anonymously, and with relatively little price impact (cite). Most previous research on market liquidity focused on stock markets or equity options markets, with little attention to the liquidity of commodity options markets. Market liquidity changing events may themselves have a direct impact on stock prices such as that observed by Amihud, et al. (1997) and Berkman and Eleswarapu (1998). Both of these studies find a strong positive relation between abnormal returns[4] and liquidity enhancing events on the Tel Aviv and Bombay Stock Exchanges, respectively.

While increasing market liquidity is generally viewed as desirable, it is difficult to measure directly. One proxy is trading volume (Blume, Easley, and O'Hara 1994).

Pricing Efficiency

Trading volume, while expected to be positively related to pricing efficiency, measures it only indirectly measure for it. There are other measures that more directly measure pricing efficiency and most importantly how it might differ between DOPP-subsidized and other trades. Of course, if there were enough trades to allow direct a comparison, we could compare DOPP vs. non-DOPP options over the same strike prices trading at roughly the same time. The dairy options markets are much too thin for these comparisons since there are long periods of time during which no trading occurs for options at many strike prices for a particular contract months. Indeed, it is common that no trades take place for many contract month and strike combinations over multiple days.

[4] the actual return minus the estimated return if there were no liquidity enhancing event.

Bid-Ask Spread. One of the most frequent proxies for liquidity is the bid-ask spread, defined as the difference between what buyers are willing to pay and what sellers are asking for in terms of price. The bid-ask spread is reported by the exchange. A market is liquid if traders can sell or buy many shares quickly at relatively low bid-ask spreads. The bid-ask spread reflects the average cost of a round-trip transaction and, therefore, compensates suppliers of liquidity and measures financial market friction. As a result, a negative relationship is expected between the bid-ask spread and liquidity.We do not use the bid-ask spread in our analysis because the dairy options market is thin enough that there may be recorded bids/asks for offers that from the data appear to go unfilled for the entire day. The data is not detailed enough to know how a bid or an ask price for a given day relates to the actual differences between potential buyers and sellers of options.

Predicted vs. Actual Options Prices. There are a number of models that provide predictions for options prices based on the characteristics of the options and its underlying futures contract. These models are widely used by traders at many levels, but require some important simplifying assumptions, particularly with respect to the assumed distribution for the underlying futures contract. The prices predicted by these models can be compared with the prices observed in the market, with these differences providing a measure of pricing efficiency. Our empirical analysis will make use of these price differences, focusing on how these differences change between DOPP and non-DOPP options trades.

When futures prices are assumed to be log-normally distributed, then Black's well-known formulas for computing the price of a (European) call and put option are:[5]

(1a) $C = e^{-rT}[F\Phi(d_1) - S\Phi(d_2)]$

[5] "European" options do not allow exercise before expiration, while "American" options do. This constraint should reduce the value of European relative to American options, but this difference is expected to be small for options of commodity futures (Hull; Campbell, Lo, and MacKinlay; Buschena and Ziegler).

(1b) $P = -e^{-rT}[F\Phi(\text{-}d_1) - S\Phi(\text{-}d_2)]$ where,

$d_1 = [\ln(F/S) + (Tv^2)/2]/(\sqrt{T}v)$

$d_2 = [\ln(F/S) - (Tv^2)/2]/(\sqrt{T}v)$

$\Phi()$ = standard normal distribution function

F = price of underlying futures contract

S = option strike price

v = volatility measure (%)

T = time to expiration (number of days until expiration / 365)

r = risk-free interest rate

C = call option price

P = put option price.

If the volatility parameter (v) is known, one can easily determine fair-market prices for a call and put option. On the other hand, an observed option price can be used to infer the market's assessment of the underlying futures price volatility, commonly referred to as the implied volatility (see Fackler and King (1990); Sherrick, Garcia and Tiruppatur (1996)). The implied volatility measures the uncertainty that market participants have concerning the futures price over the remaining life of the option contract. Information flows and changes in market conditions change the implied volatility as traders adjust their forecasts of future price variability. Several studies have examined the behavior of option prices and implied volatility around news announcements (i.e., Ederington and Lee 1996; McNew and Espinosa 1994; Fortenbery and Sumner 1993; Monroe 1992). Although some empirical models have been developed to identify factors influencing actual price volatility in futures markets (Andersen 1985; Kenyon, et al. 1987), relatively little empirical modeling has been done to explain changes in implied volatility based on market factors.

The assumptions of the Black model do not always hold. Sherrick, Garcia, and Tirupattur (1996) found the relative fit of the log-normal distribution for explaining options prices to be statistically inferior to that for more flexible distributional forms for soybean options contracts, though the resulting differences in estimated options prices were small in economic terms. Another application of tests for distributional forms in Buschena and Ziegler (1999) showed that the relative fit of the log-normal distribution to be comparable to that of more flexible forms for corn and soybeans. Assessing the relative fit of these distributions is particularly difficult when markets are thin. When the log-normal distribution fits poorly, a portion of the pricing error appears to be due to prices for options far in- or out-of-the-money, giving rise to options pricing patterns known as a "volatility smile" (Hull). These far in- and out-of-the money options trade at lower volumes than do options that have lower absolute intrinsic values.

Despite their potential errors, the use of Black's pricing formulas are a tractable method to evaluate the pricing efficiency of trades, particularly those involving DOPP purchases relative to those that were not. By correcting for measurable aspects of trading ─ the options moneyness (difference of the strike price and the futures price), the time remaining for the option, the volatility of the futures markets, calls and puts, and other factors ─ our analysis will evaluate differences between the theoretical prices in equations and (1) and (2) and the actual options sales prices. We are particularly interested in how these price differences vary between DOPP subsidized puts and non-DOPP puts, how they vary with volume, and how they vary with brokers who fill a large number of DOPP orders. This analysis will use data that encompasses both DOPP and non-DOPP trades and trading periods, and both puts and calls.

Data Description

DOPP transactions data were made available by the USDA's Risk Management Agency. These data for each DOPP purchase includes: a producer code; a broker code; the option's strike price, the option's premium, and the date/time of the transaction.

Producers that participate in DOPP had the opportunity in some rounds to buy put options from different milk options markets as well as different contract sizes. Both the CME and the NYBOT (formerly the CSCE) allowed trading in milk futures and options markets during most of the DOPP periods, although each market offered different contract sizes. The CME milk futures contract is a 200,000-pound contract while the NYBT contract was a 100,000 pound contract of milk. Each contract offered options on corresponding futures contracts of the same contract size. The exchanges also offered options contracts over futures of different sizes. The CME offered a 50,000 lb., a 100,000 lb., and a 200,000 lb. options contract during the DOPP period (the 50,000 pound contract was discontinued after DOPP's Round 2), while the NYBT offered both a 100,000 and a 200,000-pound option contract.

While these two options venues provided producers with alternative sizes to more closely meet their needs, they also served to fragment the already thin market. Indeed, by June of 2000 the NYBOT delisted milk futures and options contracts due to lack of trading activity.

As such, we focus only on the CME's 200,000 pound option contract. Because this contract is the same size as the CME futures contract profitable pricing opportunities between these options market should have been arbitraged away in the corresponding futures market absent market friction.

Table 1 lists options volume traded under DOPP for all four rounds. Along with the DOPP transactions data, we also acquired data on milk futures and options trading from the CME. Two datasets were utilized: (1) end-of-day data and (2) time and sales data. The former provides settlement prices for all available futures and options contracts, while the latter provides point-in-time transactions data on all futures and options.

We utilize these data in a two-step procedure to evaluate the pricing efficiency of DOPP options transactions. First, the end-of-day data is utilized to determine the implied volatility for each option contract. This is done utilizing Black's formulas presented earlier as (1a) and (1b) for calls and puts, respectively. Given observed options premiums and futures prices at the end of each trading day, we then compute numerically the implied volatility that provides the closest theoretical premium to the observed premium.

Given the implied volatility for each option, we then examine the following day's trading activity utilizing the time and sales dataset. This data provides transaction-level observations on futures and options throughout the day. For each options transaction, we then compute the pricing error. The formula for the Put Pricing Error is:

(2) $\text{Put Pricing Error} = e_\tau = P_\tau - P(F_\tau, v_0)$

where P_τ is the observed (actual) put option premium at time τ and $P(\cdot)$ is Black's put option pricing formula, where we utilize the implied volatility from the previous day's close (v_0) and the futures price (F) for time period τ.

In an efficient market with active trading, pricing errors are expected to be close to zero. The central hypothesis we test is that the systematic component of pricing errors differs for options purchased under the DOPP program from those purchased outside the program. The pricing errors are modeled generally as:

(3) $e_{\tau} = f(D, M, T, V, \underline{B}, v_0) + ,_{\tau;}$

where D is an indicator variable taking the value 1 for options purchased under the DOPP program (0 otherwise), M is the option's moneyness, T is the options time (remaining) to maturity, V is the option's trading volume, $\underline{B}$ is a vector of broker indicator variables, and v_0 is the previous day's implied volatility as discussed above.[6] The cross-section and time-series nature of our data allows us to test for the effects of each of these variables on pricing errors.

We hypothesize a non-zero effect for each variable. The DOPP variable will be tested using a two-tailed test. Moneyness is predicted to increase pricing errors in absolute (rather than relative) terms. The time to maturity is hypothesized to increase pricing error due to thin trading activity for options that are far from maturity. The options trading volume is a proxy for market efficiency and is hypothesized to decrease pricing errors. Indicators for those brokers with the largest DOPP volume will be tested for significance using two-tailed tests. The option's implied volatility will be tested using a two-tailed test.

Comparisons of Means

Options Trading Volume. The CME dairy futures and options market are a relatively small-volume market compared to futures and options markets for other agricultural products. Volume and open interest in futures and options on the CME dairy contracts have grown over time, however, CME futures contract volume averaged only 283 contracts in January 1999, but by December 2002 the average daily volume and grown to nearly 500 contracts per day. Dairy options volume over this period also nearly doubled.

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[6] Moneyness defines the option's intrinsic value (if positive) if exercised today. For puts, moneyness is the difference between the strike price and the futures price; for calls, moneyness is the difference between the futures price and the strike price.

DOPP's first round began in January 1999 and Round 4 of DOPP ended in early 2003. To assess the effects of DOPP trades on options and futures markets, we calculated daily total volume across all delivery months for futures, puts and calls. Single-equation regressions for each market were performed using DOPP trading volume and a time trend variable. If the DOPP volume variable is statistically significant, this would indicate that DOPP volume had an impact on trading volume in the corresponding derivative market. Of most interest is the magnitudes of the DOPP volume coefficients in all three regressions. If this coefficient is larger than 1.0, there is a DOPP "multiplier effect" from this subsidized options program on volume.

Although the DOPP coefficient for the put equation is greater than 1 in Table 2, we cannot reject the hypotheses that it equals 1. The DOPP volume coefficients in both the futures and call options markets are not significantly different from zero. As such, there is no statistically significant multiplicative impact of DOPP volume in the put market. That is, beyond the initial trade of a DOPP put, there appears to be no statistically significant additional trading generated in any of the markets. Note, however, that DOPP's educational component might have led dairy producers to explore the use of options in the long term; this potential effect cannot be effectively tested with the data we use in this paper. Note further that there was a significant positive time trend for trading volume in each market.

Pricing Errors. Population means for the pricing errors for DOPP and non-DOPP put options trading during the four DOPP rounds combined and separately are presented in Tables 3a-3e. These values are in dollars per hundredweight. The pricing errors for puts purchased under DOPP are significantly (statistically and economically) higher under DOPP for the entire period and in every DOPP round separately. The pricing error differences between puts under DOPP and both non-DOPP puts and calls, were significantly positive. DOPP options were significantly more expensive relative to their theoretical options price in their means, despite their theoretically lower value due to the program's restriction that they be held until a time at least one month prior to expiration.

Brokers filling DOPP option orders were identified in the data set. The mean pricing errors for each of the brokers are given in Table 4. Some brokers have been quite active in filling these DOPP orders, with the top four brokers handling 64% of all DOPP trades. Some of these high DOPP trade volume brokers appear to be filling orders at relatively high prices for these options when actual and theoretical prices are compared.

Regression Analysis of the Effects of DOPP on Options Prices

The differences between the actual options price the predicted prices were fit with linear regression models using a set of explanatory variables. Some of these variables relate to the overall options market and others relate to the DOPP program. The DOPP-related variables are of primary interest.

Single equation models were first run for puts and calls separately, and then these data were pooled. Systems models were not used because of the non-regular occurrence of the data. Some days had multiple puts and multiple calls traded, others had multiple puts (calls) but single or no calls (puts), while still other days had single puts or calls traded. The dependent options pricing differences were defined both as levels (actual price-predicted price) and as ratios where the options price difference was normalized by the predicted options price. Both definitions of this dependent variable gave qualitatively largely similar results for the effects of the DOPP variables.

The regression analyses included corrections for heteroscedasticity (White's) and a multi-period lagged structure for the dependent option pricing error variable. The time period used is the most recent trade, rather than a day's length. The duration of the lag structure (n) was determined by sequentially adding lag terms until the additional (n+1) lag was insignificant. Both the pooled and the call/put regressions included lags of four to five periods. Thus, the pricing differences have some persistence in the data we evaluated.

Explanatory Variables. The set of explanatory variables related to the DOPP program included an indicator variable for a DOPP trade, the volume of DOPP trades that day, an interaction term of the DOPP indicator multiplied by the option's moneyness to allow for differential DOPP effects, and indicators for each of the four largest brokers by volume participating in DOPP trades. Tables 5 and 6 provide descriptive statistics for the explanatory variables. These four brokers had clearly larger volume than did the remaining set of brokers, and their combined share of the DOPP trades increased over the rounds, from 14% of the total DOPP trades in Round 1 (two of the four brokers were active) to 52% of the total DOPP trades in Round 2, 82% in Round 3, and 87% in Round 4. We are particularly interested in whether or not trades made through these brokers were more or less "expensive" to their clients, where this expense is measured by the options pricing differences we use as our dependent variable.

The set of explanatory variables related to the general options markets include: measures of the daily options' trading volume over all strikes and all delivery months; the option's moneyness (strike - futures for puts; futures - strike for calls) and moneyness squared; the difference between the most recent futures price and the previous day's futures close; and the number of days before the option expires. The moneyness variable and its square are included to account for the implied volatility smile (Hull), while the other variables account for market thinness or factors affecting our predicted options price.

We run the following regression models for levels and ratios of the options price differences, adjusting this model slightly for runs over puts and calls separately, and all options pooled:

(4) $[P-\Phi]_t = \alpha_0 + \beta'\mathbf{D} + \gamma'\mathbf{O} + \lambda'\mathbf{[P-\Phi]}_{(t)} + \varepsilon_t.$

The actual options price in equation (2) is P. The symbol Φ denotes the predicted price for the option. The vector **D** includes variables related to the DOPP program. The vector **O** includes measures of the dairy options market. The vector $\mathbf{[P\text{-}\Phi]}_{(t)}$ denotes the lag structure of the options price difference that allows for persistence in these price differences. The error term ε_t is assumed to be a draw from an i.d. normal distribution with a heteroscedastic component that is correct with the White's estimator.

Pricing Differences for Puts

The results from the pricing differences in levels (Column A) and relative differences (Column B) estimates for puts are given in Table 7. There was significant persistence in the lagged dependent variable up to four periods for levels and up to five periods for ratios; these lag effects are omitted in the table to allow focus on the key variables of interest. All of the coefficients on these lagged terms were estimated to be less than one and were monotonically decreasing. The largest coefficient estimate for levels (ratios) was for the first lag at .27 (.14) and the smallest was for the fourth (fifth) at .07 (.02).

Level. Our focus is on the DOPP variables, including the indicator variables for the brokers with the highest number of DOPP trades. DOPP trades were significantly higher priced, with this coefficient estimate of 5.0 indicating a 5 cent difference between the actual and the predicted options price.[7] Larger daily DOPP volume decreased the price error for all options, a positive externality of the DOPP program. The interaction term between the DOPP indicator and the option's moneyness was not significantly different from zero.

We had some concern about the potential for an errors in variables problem regarding the DOPP volume variable. Because of a lack of clearly useful instrumental variables for this DOPP volume, we also estimated each one of the regression models using the one-period lag of this DOPP volume in place of the DOPP volume variable. The estimation results for levels were very robust in both a qualitative and a quantitative sense; there was very little change in the estimation results for the other variables, and the coefficient on the lagged DOPP volume was again significant and negative for the regressions reported in Tables 7 and 8 for both puts and calls. One qualitative difference did arise for this alternative specification using the lagged DOPP volume in the put error ratio model (Column B, Table 7). The coefficient on the lagged DOPP volume variable was insignificant, while the other coefficient estimates were relatively unchanged in this regression model.

Two of the four largest brokers sold options at significantly higher prices, with one broker's order fills estimated to be 2.5 cents per pound higher and the other estimated to be 3.2 cents per pound higher. The interpretation of these broker coefficients requires some care. The brokers (1) may be taking advantage of the options purchasers by overcharging them, (2) may be giving the purchasers the level of services they are entitled to with the (somewhat lower than the going rate) $30 fixed round-turn fee level, or (3) may be serving

[7] These effects did not decrease over time in an alternative regression formulation using an interaction term between the DOPP indicator and time. Indeed, the qualitative and quantitative results on the DOPP effects were quite robust to alternative specifications, including correcting for the DOPP round, interactions between the broker dummies and the rounds, broker-time interactions, and alternative lag structures.

their clients wishes by filling orders quickly (at the market orders rather than set price orders). Our data does not allow us to directly test these three scenarios, but we offer some additional information below.

Another scenario regarding these broker dummies is for some collusion to be taking place between the broker and the option buyer, for example by the broker selling the high-priced put in the market in conjunction with the client's put purchase. There were actions taken against two separate brokers who encouraged and carried "wash sales" transactions in which the producer bought a DOPP put option and simultaneously sold a put option at the same strike price thorough a different account (CFTC 2002). These brokers carried out these trades during the first DOPP round. The USDA-Risk Management Agency prohibits any such actions by DOPP participants that serve to nullify the hedge provided by the DOPP put.

If the large brokers were taking advantage of their clients by selling their services at too high a price, one would expect that these brokers to lose market share over time, and that these broker effects would decline over time. The percentage of DOPP trades handled by the "most expensive" brokers, #1 and #3, generally increased over time, consistent with the options buyers receiving some type of benefit from using these brokers. Additional regression runs showed these broker effects to significantly increase over time.

The non-DOPP measures influencing the options price differences are informative. Higher daily volume in the put markets statistically significantly decreases the options price errors, while total option volume (puts and calls) increases this price error. Both effects are small in economic terms. The higher the options moneyness (the less out-of-the money) and its square, the significantly lower is the options price. The options price is larger the bigger the difference between the most recent futures price and its previous day's close, reflecting either market volatility, errors in our options pricing formula, or market thinness. The larger the option's days to maturity, the lower is the pricing difference.

Relative Price Differences. The DOPP variable effects for the relative price differences were qualitatively largely unchanged from those for the levels regressions. DOPP trades were carried out at relatively higher prices and DOPP volume benefited the market generally. One difference for these estimation results is that all of the high-volume broker indicator variables are significant, with Brokers 1 and 3 filling orders at high relative prices. As for the levels regressions, these Broker effects are robust to alternative specifications.

The coefficient estimates for the effects of the general options market terms were generally consistent with those from the levels regression in Column A. The exceptions to this consistency were the sign and significance level of the squared moneyness term (which now supports the volatility smile), and the days-to-maturity term is now significant at the 10% level.

Pricing Differences for Calls

The results from the pricing difference in levels (Column A) and relative differences (Column B) estimates for calls are given in Table 8. There was significant persistence in the lagged dependent variable up to four periods for levels and for ratios. All of the coefficients on these lagged terms were estimated to be less than one and were monotonically decreasing. The largest value of these coefficients for levels (ratios) was for the first lag at .21 (.14), while the smallest was for the fourth lag at .05 (.05).

Levels. The DOPP program had positive effects on this thin call market in total; higher DOPP volume decreased call prices relative to the predicted level.

The effects of the general options markets variables on call markets are somewhat different from those for puts. Coefficient estimates on the moneyness and moneyness squared terms support a significant volatility smile. Larger changes in the futures price from the previous day's close (making the call at a specific strike cheaper) reduced the call option's price. Longer days to maturity increased the difference between the call price and its prediction; this estimated coefficient has the opposite sign it did for puts. Contrary to the results for puts, the trading volume for calls and for combined options trades were insignificant.[8]

Relative Differences. Defining the dependent price errors as a relative difference gave qualitatively different results than for levels (Column B). DOPP volume had no significant effect on the relative difference between the call price and its prediction. Of the two terms on the option's moneyness, only the squared term was significant. Call options prices were significantly more expensive than their predicted prices as the days to maturity increased.

Pricing Differences for Calls and Puts, Pooled

The results from the pricing difference levels (Column A) and relative differences (Column B) estimates for puts and calls pooled are given in Table 9. The lag effects of previous options trades are modeled differently in this regression than those above; here any recent previous option trade, call or put, is allowed to influence the pricing difference of the current option trade, call or put. This lagged effects treatment is supported by the close relationship through put-call parity between options prices.

There was again significant persistence in the lagged dependent variable of up to five periods for levels and for four for ratios. All of the coefficients on these lagged terms were

[8] Removing the call option volume term from the regression did not make the overall option volume significant.

estimated to be less than one and were monotonically decreasing. The largest value for these lagged coefficients for levels (ratios) was the first term at .22 (.14), while the smallest was for the fifth (fourth) lagged term at .05 (.07).

Levels. DOPP put trades were significantly more expensive relative to the predicted price than were non-DOPP puts (the base case in this regression). This estimated price difference effect was 5.3 cents per pound, very close to the 5.0 cent per pound estimate for the puts regression in Table 2, Column A. As was the case in the separate puts and calls regressions, DOPP volume significantly reduced the difference between all option's price and its predicted level generally, and there were additional negative price difference effects for call options. The DOPP effect did not depend significantly on the option's moneyness. The broker effects for DOPP puts for the four largest brokers by option volume were consistent with the effects when only puts were considered in the regression (Table 2).

Call options were cheaper with respect to their predicted price in this pooled regression. Option moneyness significantly reduced the difference between the options price and its prediction; moneyness squared was insignificant when added to an alternative specification. There were no significant general volume, days-to-maturity, or futures change effects for this levels regression.

Relative Differences. Defining the dependent price difference variable as a relative difference gave qualitatively different results than for levels for this pooled set of options (Column B). The price differences between DOPP puts and their predicted value were larger than for non-DOPP puts. Options were lower priced (relative to their predicted costs) as DOPP volume increased; calls were additionally cheaper with this value. A volatility smile was evidence from the coefficients on the option's moneyness and moneyness squared terms.

Options prices were significantly more expensive than their predicted prices as the days to maturity increased, and as the difference between the most recent the previous day's futures price increased. There were significant Broker effects for Broker 3 (positive) and for Brokers 2 and 4 (negative).

Conclusions

This paper provides a brief overview of the impact of the subsidized Dairy Options Pilot Program (DOPP) on the underlying options market. This DOPP was designed as an educational tool to increase dairy farmer's knowledge of options markets with an eye to the promise of such program toward reducing producer reliance on government price protection policies. Such programs have also been touted as having the potential to improve overall market performance through the increased trading volume. This paper addresses this second goal of DOPP.

We find that DOPP options purchases were expensive relative to these options' theoretical prices. This measured additional expense for DOPP trades was statistically and economically significant when measured at population means; these differences are significant for both non-DOPP puts and for calls, and in every DOPP trading period. We were able to identify and test for the effects of specific brokers who filled DOPP trades on the pricing errors and found statistical evidence consistent with some brokers filling DOPP orders at relatively high prices.

The results of the statistical analysis in this paper are supported by a more detailed analysis designed to further isolate the effects of DOPP from those from other factors. The results of this more detailed analysis are available from the authors, and will be discussed in a forthcoming paper.

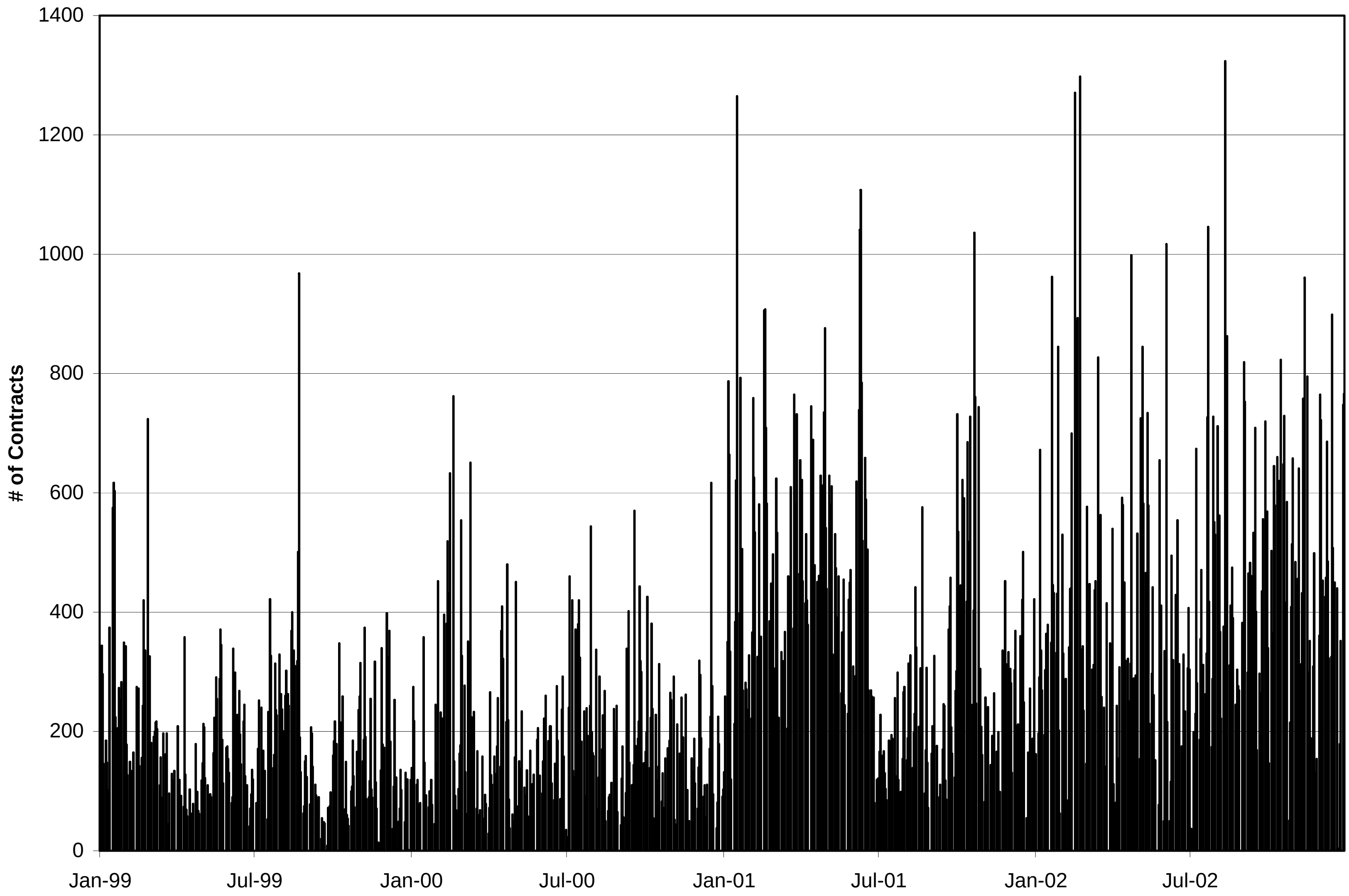

Figure 1. CME dairy futures trading volume: 1999-2002.

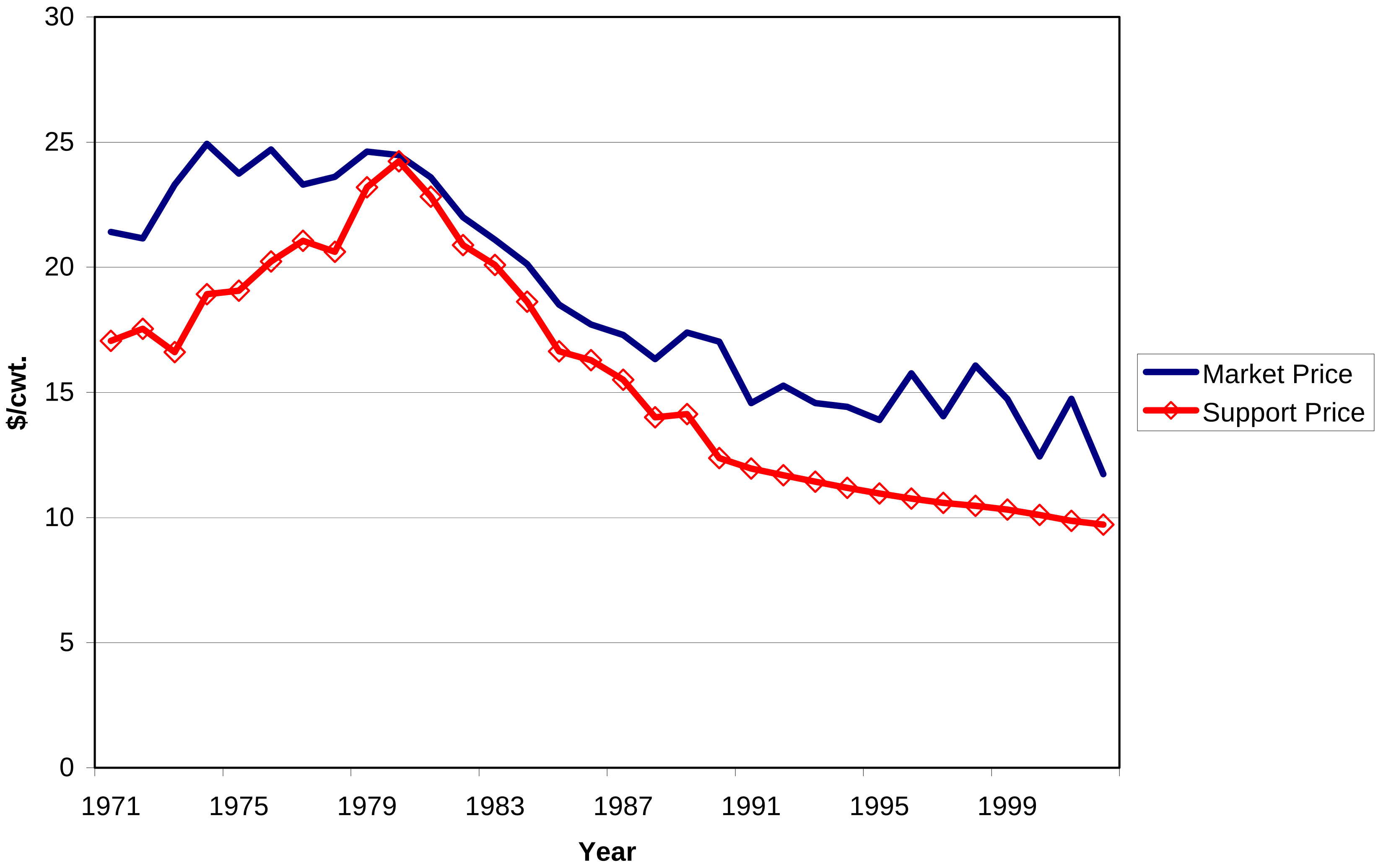

Figure 2. Fluid milk market and support prices.

Table 1. DOPP Participation by Round and Number of Contracts.

	CME 200,000 Pound Options		**Other Options**[1]	
Round	**Producers**	**Contracts**	**Producers**	**Contracts**
1	160	324	339	1377
2	100	242	29	68
3	415	1013	458	1809
4	291	943	239	733

[1]Includes CME's 50,000 and 100,000 lb put options, NYBT 100,000 and 200,000 lb put options and CME's Class IV milk put options.

Table 2. Single Equation Regression Results for the Effect of DOPP Volume on Total Trading Volume.

	Dependent Variable		
	Futures Volume	**Put Volume**	**Call Volume**
Intercept	127.5	18.55	16.13
	(0.001)	(0.001)	(0.001)
DOPP Volume	0.969	1.362	0.014
	(0.419)	(0.001)	(0.961)
Time Trend	0.298	0.028	0.036
	(0.001)	(0.001)	(0.001)
R^2	0.174	0.060	0.052

p-values in parentheses

Table 3a. Intra-Day Options Error Averages: January 1999 – October 2002.

Option Type	Mean Error	Std Error	Observations	T-stat
DOPP Puts	6.20	0.169	1,158	36.70
Non-DOPP Puts	-0.26	0.088	5,146	-2.93
Calls	-0.65	0.096	3,851	-6.85

Table 3b: Intra-Day Options Error Averages During Round 1: January 20, 1999 – June 23, 1999.

Option Type	Mean Error	Std Error	Observations	T-stat
DOPP Puts	4.96	0.342	203	14.49
Non-DOPP Puts	0.06	0.177	663	0.35
Calls	-0.88	0.254	385	-3.46

Table 3c. Intra-Day Options Error Averages During Round 2: May 12, 1999 – January 23, 2001.

Option Type	Mean Error	Std Error	Observations	T-stat
DOPP Puts	4.67	0.381	168	12.28
Non-DOPP Puts	-0.11	0.385	467	-0.28
Calls	0.99	0.176	676	5.61

Table 3d. Intra-Day Options Error Averages During Round 3: March 30, 2001 – January 17, 2002.

Option Type	Mean Error	Std Error	Observations	T-stat
DOPP Puts	6.14	0.269	543	22.78
Non-DOPP Puts	-0.28	0.149	1645	-1.90
Calls	-1.78	0.271	902	-6.57

Table 3e. Intra-Day Options Error Averages During Round 4: May 22, 2002 – October 31, 2002.

Option Type	Mean Error	Std Error	Observations	T-stat
DOPP Puts	8.43	0.321	244	26.26
Non-DOPP Puts	0.05	0.251	516	0.21
Calls	-0.39	0.163	594	-2.39

Table 4. DOPP Broker Means.

Broker Id	Mean Error	Std Error	Observations	T-stat
89	7.71	0.643	101	11.99
91	7.26	0.336	351	21.61
94	5.92	0.338	291	17.06
98	8.67	0.429	251	20.20
99	6.12	0.796	49	7.69
100	5.71	0.734	49	7.78
101	1.33	.	3	.
103	-1.00	0.632	5	-1.58
104	5.89	0.730	38	8.07
106	5.42	0.709	36	7.63
107	4.67	0.505	64	9.24
109	3.56	1.074	25	3.31
110	4.55	0.277	281	16.46
112	3.89	0.465	80	8.36
115	6.56	0.922	18	7.11
117	1.63	0.905	8	1.80
118	2.18	0.732	33	2.98
122	5.75	1.234	8	4.65
124	-4.00	.	2	.
126	6.67	1.447	12	4.60
131	2.67	.	3	.
132	3.27	0.278	114	11.76

Table 5. Descriptive Statistics, Put Regression.

Variable	**Mean**	**St. Dev.**	**Min.**	**Max.**	**Obs.**
Option Pricing Error	1.11	7.38	-60.0	103.0	6350
DOPP Trade Indicator	.18	.39	0.0	1.0	6350
Daily DOPP Option Volume	4.03	7.84	0.0	73.0	6350
Daily Put Option Volume	54.6	60.5	0.0	594.0	6350
Daily Total Option Volume	91.5	81.2	0.0	612.0	6350
Option Moneyness	-31.9	89.6	-440	475	6350
Futures Price Change	.72	13.8	-113.0	94.0	6350
Option's Days to Maturity	112.5	70.5	1.0	396	6350
Broker 91, DOPP Trades only	.17	.38	0.0	1.0	1157
Broker 94, DOPP Trades only	.19	.39	0.0	1.0	1157
Broker 98, DOPP Trades only	.15	.36	0.0	1.0	1157
Broker 110, DOPP Trades only	.15	.36	0.0	1.0	1157

Table 6. Descriptive Statistics, Call Regression.

Variable	**Mean**	**St. Dev.**	**Min.**	**Max.**	**Obs.**
Option Pricing Error	-.58	6.09	-60.0	45	3867
DOPP Option Volume	2.21	5.20	0.0	73.0	3867
Daily Call Option Volume	51.8	52.8	0.0	598.0	3867
Daily Total Option Volume	93.4	79.0	0.0	612.0	3867
Option Moneyness	-57.3	88.1	-440	453	3867
Futures Price Change	-1.09	13.3	-103.0	90.0	3867
Option's Days to Maturity	105.8	67.3	1.0	382	3867

Table 7. Heteroscedasticity Corrected Linear Regression with Dependent Variable Lags. Actual/Predicted Price Differences for Fluid Milk Put Options.

	A: Differences in Levels	B: Differences in Ratios
Constant	-.252 (.184)	-.040*** (.009)
DOPP INDICATOR	5.01*** (.447)	.109*** (.008)
DOPP VOLUME	-.044*** (.009)	-.7E-03** (.3E-03)
DOPP*MONEYNESS	.021 (.019)	.4E-04 (.3E-03)
MONEYNESS	-.008*** (.001)	-.2E-03*** (.3E-04)
MONEYNESS SQUARED	-.10E-06* (.5E-05)	.1E-05*** (.2E-06)
PUT OPTION VOLUME	-.01*** (.2E-02)	-.3E-03*** (.1E-03)
TOTAL OPTION VOLUME	.005*** (.002)	.1E-03** (.7E-04)
DAYS TO MATURITY	-.003*** (.001)	.8E-04* (.5E-04)
CHANGE IN THE FUTURES PRICE	.069*** (.011)	.002*** .3E-03
BROKER 91 INDICATOR	2.47*** (.420)	.02*** .7E-02
BROKER 94 INDICATOR	.285 (.429)	-.02** (.007)
BROKER 98 INDICATOR	3.17*** (6.47)	.02*** (.8E-02)
BROKER 110 INDICATOR	-.530 (.412)	-.03*** (.7E-02)
LAG STRUCTURE	four periods	five periods
	n=6346, Adj. R-squared=.33	N=6345, Adj. R-squared=.10

* indicates significance at the 10% level, ** significance at the 5% level, and *** significance at the 1% level.

Table 8. Heteroscedasticity Corrected Linear Regression with Dependent Variable Lags. Actual/Predicted Price Differences for Fluid Milk Call Options.

	A: Differences in Levels	**B: Differences in Ratios**
Constant	-1.72*** (.224)	-.155*** (.019)
DOPP VOLUME	-.073*** (.202)	-.16E-02 (.12E-02)
MONEYNESS	-.008*** (.001)	-.3E-04 (.8E-04)
MONEYNESS SQUARED	.2E-04*** (.5E-05)	.2E-05*** (.4E-06)
CALL OPTION VOLUME	.002 (.3E-02)	-.1E-03 (.2E-03)
TOTAL OPTION VOLUME	.7E-03 (.002)	.8E-04 (.1E-03)
DAYS TO MATURITY	.006*** (.001)	.7E-03*** (.1E-03)
CHANGE IN THE FUTURES PRICE	-.034** (.013)	-.9E-03 .8E-03
LAG STRUCTURE	four periods	four periods
	n=3864, Adj. r-squared=.12	N=3864, Adj. r-squared=.04

* indicates significance at the 10% level, ** significance at the 5% level, and *** significance at the 1% level.

Table 9. Heteroscedasticity Corrected Linear Regression with Dependent Variable Lags. Pooled Sample of Actual/Predicted Price Differences for Fluid Milk Options.

Constant	-.64*** (.16)	.07*** (.91E-02)
DOPP INDICATOR	5.29*** (.46)	.11*** (.96E-02)
DOPP VOLUME	-.25E-01*** (.94E-02)	-.68E-03** (.32E-03)
DOPP MONEYNESS	.02 (.02)	-.234E-03 (.33E-03)
CALL INDICATOR*DOPP VOLUME	-.14*** (.03)	-.20E-02* (.11E-02)
CALL INDICATOR	-.50*** (.14)	-.06*** (.87E-02)
MONEYNESS	-.01*** (.82E-03)	-.20E-03*** (.32E-04)
MONEYNESS SQUARED		.15E-05 (.18E-06)
OPTION VOLUME	.46E-03 (.75E-03)	-.25E-04 (.40E-04)
DAYS TO MATURITY	.31E-03 (.84E-03)	.32E-03*** (.52E-04)
CHANGE IN THE FUTURES PRICE	.78E-02 (.01)	.12E-02*** (.40E-03)
BROKER 91 INDICATOR	2.42 *** (.43)	.01 (.85E-02)
BROKER 94 INDICATOR	.59 (.46)	-.02*** (.80E-02)
BROKER 98 INDICATOR	3.27*** (6.46)	.02** (.95E-02)
BROKER 110 INDICATOR	-.545 (.430)	-.04*** (.85E-02)
LAG STRUCTURE	Five-period	Four-period

* indicates significance at the 10% level, ** significance at the 5% level, and *** significance at the 1% level.

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