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Subsidized Options in a Thin Market: The Dairy Options Pilot Program

Introduction

Put options have been recommended as a substitute for price support programs (Gardner 1977), and subsidization programs have been offered on a limited basis to enhance producer experience with options (Glauber and Miranda 1989). Put options provide flexibility with regard to market conditions, but one concern of their use is the thinness of some options markets in which the market lacks a sufficiently large number of traders willing to take positions in lieu of a relatively large price premium. This paper provides an empirical investigation of a subsidized option purchase program on such a thin market, options on milk futures.

Trading volume in milk futures and options remains well below that for other agricultural commodities. Closing market reports show daily trading volume for the CME's Live Cattle futures market is thousands of contracts per day for each of the nearby delivery months while the CME Class III milk futures contract trading volume is typically well under 100 contracts per day for these months.

This paper empirically assesses how the thin dairy options market responded to trade volume increases brought about the subsidy program. More than 1,300 producers purchased options under the Dairy Options Pilot Program (DOPP) at subsidies totaling over $5 million (Vandeveer, et al. 2004). During the period in which the DOPP program was active, 16% of all put purchases were subsidized through this program. We empirically assess (1) the prices of subsidized options relative to unsubsidized options, and (2) whether or not subsidized options purchased affected other milk options. In addition, we develop empirical procedures to assess whether brokers provided acceptable service for these subsidized options purchases.

Dairy Options Markets and the DOPP Program

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).[1] In January, 1996 the CME also began trading fluid milk contracts that competed directly with NYBOT contracts.

Milk futures contracts on both exchanges initially used the USDA's Basic Formula Price[2] (BFP) as their price measure. Contracts were for 100,000 lbs. BFP milk at the NYBOT and 200,000 lbs. at the CME; the NYBOT contract size translates to the monthly milk output from approximately 60 cows. The USDA announced a new Class III formula in January 2000 that replaced the BFP formula. Consequently, both exchanges shifted their contract specifications to Class III milk.[3]

Because of low trading volumes, milk futures and options trading were terminated on the NYBOT in June 2000. The CME continues to trade Class III fluid milk futures and options, with some recent growth evident in trading volume for these contracts that does not appear to be solely due to the ending of trading on the NYBOT.

The Dairy Options Pilot Program (DOPP)

DOPP was developed by the USDA's Risk Management Agency in collaboration with the NYBOT, the CME, the USDA's Economic Research Service, and the Commodity Futures Trading Commission. DOPP was designed to teach producers how fluid milk put options could be used to provide price protection. More than 6,000 dairy producers participated in DOPP, comprising somewhat over 5% of total U.S. dairy farms (Vandeveer, et al. 2004). Vandeveer, et al. offers a complete description DOPP's origin and administration.

The USDA cost-share arrangement subsidized the purchase of put options by paying 80% of the put option's price and up to $30 of commission fees.[4] 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.[5] Producers could participate in multiple rounds of DOPP. The four rounds of DOPP had varying trading dates and availability:

Round 1 from January-June 1999. Available in 38 counties in 7 states;

Round 2 from May, 2000 to Jan., 2001. Available in 61 counties in 32 States;

Round 3 from March, 2001 to Jan., 2002. Available in 275 counties in 39 states;

Round 4 from in May, 2002 to Jan., 2003. Available in 300 counties in 40 states.

Producers could not purchase more than 600,000 lbs. of DOPP put options during a year nor more than 200,000 lbs. in any given month (Vandeveer, et al. 2004). Thus the purchase maximum was either one CME contract or two NYBOT contracts. Many producers produced more than these maximums in their dairy operations.

DOPP options purchased were required to have at least two months, but not more than twelve months, remaining before expiration at the time of purchase. Producers were required to hold DOPP options until one month prior to expiration, after which they could exercise, sell, or continue to hold the put option. The requirement to hold the option until one month prior to expiration should have decreased the value of the DOPP option relative to freely traded options.

Measuring Market Performance

Market performance or pricing efficiency is difficult to measure, particularly in thin markets. A number of market performance proxies have been proposed including market liquidity, trade volume, and bid-ask spreads. All three of these proxies have drawbacks for our application. Trade volume is only indirectly related to market performance, while the data required to measure liquidity and relevant bid-ask spreads are not available for these thin dairy options markets. An alternative measure to assess pricing performance used here is the difference between predicted and actual option prices.

Several models provide predictions for options prices. These models are widely used but require some important simplifying assumptions, particularly with respect to the assumed distribution of the underlying futures contract. Option prices predicted by these models can be compared with observed prices, with their differences to some degree reflecting price inefficiencies in the options market. Our empirical analysis exploits the price differences across DOPP and non-DOPP options prices and evaluates the predictive power of a set of explanatory variables for explaining these differences.

When futures prices are assumed to be log-normally distributed, The Black-Scholes formulas for predicting the price of a (European) call and put option are:[6]

(1a) $C = F * \Phi(d_1) - S * e^{-rT} * \Phi(d_2)$, and

(1b) $P = S * e^{-rT} * \Phi(-d_2) - F * \Phi(-d_1)$, with

$$d_1 = [\ln(F/S) + (Tv^2)/2]/(\sqrt{T} * v), \text{ and}$$
$$d_2 = [\ln(F/S) - (Tv^2)/2]/(\sqrt{T} * v).$$

The following definitions are used in equations (1a) and (1b):

C = call option price
P = put option price.
r = risk-free interest rate
T = time to expiration (number of days until expiration / 365)
v = volatility measure (the standard deviation of the futures price distribution)
S = option strike price
F = price of underlying futures contract
$\Phi(\cdot)$ = standard normal cumulative distribution function

If the volatility parameter (v) in (1a) and (1b) is known, one can determine fair-market prices for both call and put options. Alternatively, an observed option price can be inserted as the value for the left-hand side of equation (1a) or (1b) to infer the market's assessment of the underlying futures price volatility (v), commonly referred to as the implied volatility (see Fackler and King (1990); Sherrick, Garcia and Tirupattur (1996)).

The assumptions of the Black-Scholes model do not always hold. Fackler and King (1990); Sherrick, Garcia, and Tirupattur (1996); and Buschena and Ziegler (1999) assess the relative fit of log-normal distributions relative to more flexible forms for modeling options' prices. However, these alternative price distributions do not lend themselves well to thin options markets such as for the dairy options market where there are days in which very few trades may occur for a given contract month.

We use the Black-Scholes pricing formula under a log-normal distributional assumption as a tractable method for evaluating the prices for DOPP vs. non-DOPP options. In this evaluation, we consider differences between theoretical prices predicted under either equation (1a) or (1b) and actual price the option sold for. The key explanatory variables we use include the option's moneyness (the difference between the strike and the futures prices), the time remaining for the option, the volatility of futures markets, calls vs. puts, and other factors. We are particularly interested in how these price differences vary between DOPP and non-DOPP puts, how they vary with options trade volume, and how they vary between brokers.

Data Description

DOPP transactions data were obtained from the USDA Risk Management Agency. These data include a producer code, a broker code, the option's strike price, the option's premium, and the date/time of the transaction for each DOPP purchase. We consider trades over the continuously available CME's 200,000 pound option contract from January, 1999 to January, 2003 (the time period spanning the DOPP rounds).

Table 1 lists options volume traded under DOPP for all four of the previously defined DOPP rounds. Along with the DOPP transactions data, we also obtained data on milk futures and options trading from the CME. Two CME datasets are used: (1) end-of-day data and (2) time and sales data. End-of-day data provide settlement prices for all available futures and options contracts, while time and sales data provide point-in-time transactions on all futures and options.

We use a two-step procedure to evaluate the pricing efficiency of options purchased under DOPP. First, end-of-day data is used to determine the implied volatility for each option contract by applying Black's formula using either equation (1a) for calls or (1b) for puts. Given observed options premiums and futures prices at the end of each trading day, we then compute the implied volatility that minimizes the difference between the theoretical and observed premiums.

In the second step of our procedure, the estimated implied volatility from step one is used to examine the following day's trading activity in the CME's time and sales data. For each options transaction, we compute the pricing error defined in the following formula for puts (pricing errors for calls are defined comparably):

(2) Put Pricing Error = $e_\tau = P_\tau - \pi(F_\tau, v_0)$,

where P_τ is the observed (actual) put option premium at time τ and $\pi(\cdot)$ is Black's put option pricing formula obtained from the implied volatility from the previous day's close (v_0) and the futures price (F) for time period τ. The central hypothesis tested, further discussed below, is that the systematic component of pricing errors for options purchased under the DOPP program differs from those purchased outside the program.

Comparisons of Mean Pricing Errors

Mean pricing errors in cents per cwt. for DOPP and non-DOPP put options are presented in tables 2a-2e. Pricing errors for DOPP puts are significantly (statistically and economically) higher than the non-subsidized options for the entire period and in every DOPP round, with this difference averaging almost 6 cents per cwt. for all DOPP rounds. With the average price for a DOPP option of 57 cents per cwt. during the four rounds, this DOPP option error "premium" was more than 10% of the average DOPP option's price. The pricing error differences between both (1) DOPP and non-DOPP puts and (2) between DOPP puts and calls were significantly positive. That is, DOPP options were significantly more expensive relative to their theoretical options price, 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 by a code number in the RMA data. The mean pricing errors for each of the brokers are given in table 3. Some brokers were quite active in filling these DOPP orders, with the top four brokers combined handling 64% of all DOPP trades (the bold entries in table 3). Some of these high volume DOPP brokers appear at first glance to be filling orders at relatively high prices; broker 98 and 91 had the highest mean options price error rate among the 22 brokers filling DOPP orders.

Regression Analysis of the Effects of DOPP on Options Prices

The mean pricing differences in table 2 and the broker effects in table 3 suggest that there might be differences between the prices for options purchased under DOPP and non-DOPP options.

These raw results do not however correct for a number of factors generally thought to affect options prices. In order to more completely assess the effects of DOPP on options prices, we turn to a multivariate regression analysis that allows isolation of the DOPP effects from those of other variables. We consider in these regressions all options trades—DOPP puts, non-DOPP puts, and calls—during the trading dates covered by the DOPP rounds.

The differences (prediction errors) between actual and predicted options prices were used as the dependent variable in linear regression models. Some of these explanatory variables relate to the overall options market and others relate to the DOPP program.

We run the following regression models for the differences in levels and the relative difference (predicted options price in the denominator). The variables used in the regression models differed slightly for the regressions over puts and calls. The regression equation for puts is:

(3) $$[\pi_\tau - P_\tau] = \alpha_0 + \beta'\mathbf{D} + \gamma'\mathbf{O} + \lambda'[\pi_{(\tau)} - \mathbf{P}_{(\tau)}] + \varepsilon_\tau$$

The actual put options price for observation τ in equation (3) is P_τ. The predicted price for the option sale is π_τ. The vector $[\boldsymbol{\pi}_{(\tau)} - \mathbf{P}_{(\tau)}]$ denotes the lag structure of the options price difference that allows for persistence in these price differences. The vector **D** includes variables related to the DOPP program and the vector **O** includes measures from the dairy options market. The error term ε_τ is assumed to be a draw from an independently normally distributed with a heteroscedastic component corrected using White's approach.

The well-known put-call parity relationship (Hull) suggests a pricing relationship between the separate call and put markets. Through the risk-free arbitrage relationship underlying this relationship, factors that affect one market (here puts) would affect the other (here calls). Thus, if the DOPP program affects the put market, it would likely also affect the call market. We will to test for these cross-market effects of DOPP empirically.

Single equation models were run for puts and calls separately. Systems models were not used because of the non-regular occurrence of observed option sales. This non-regularity frequently gave puts at multiple strike prices and calls at multiple strike prices traded in some days. In other days puts (calls) at multiple strike prices were traded but single or even no calls (puts) were traded. In still other days puts (calls) at only a single strike price was traded but no calls (puts) were traded.

The time period considered for the lag structure is defined by the duration between the current and the most recent trade, rather than a day's length. 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.

Explanatory Variables. The set of explanatory variables related to the DOPP program, **D** in equation (3), includes 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 who participated in DOPP trades. Tables 4a and 4b provide descriptive statistics for the explanatory variables for put and call regressions, respectively. Four brokers had clearly larger DOPP volume than other brokers did. These four brokers' combined share of the DOPP trades increased over time, from 14% of total DOPP trades in Round 1 (two of the four brokers were active), 52% of 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.[7]

The set of explanatory variables related to the general options markets (**O** in equation (3)) include measures of 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 2001), while the other variables account for market thinness or factors affecting the predicted options price using formulas (1a) and (1b).

Pricing Differences for Puts

The results from the pricing differences in levels (Column A) and relative differences (Column B) for puts are presented in table 5. There was significant persistence in the lagged dependent variable of up to four periods for levels and of up to five periods for ratios. The estimated coefficients for the lagged terms were well-behaved in that they summed to less than one and were monotonically decreasing.

Results. Our focus for the regression estimates is on the DOPP variables, including the indicator variables for the four brokers with the highest number of DOPP trades. DOPP trades were significantly higher priced (relative to their theoretical prices) that other options. For example, the DOPP coefficient estimate in the levels model of 5.0 indicates a 5 cent difference between the actual and the predicted options price.[8] This coefficient indicates an 11% larger price in relative terms for the subsidized DOPP options. Larger daily DOPP volume decreased the pricing error for all (DOPP and non-DOPP) puts traded in both models, an apparent positive externality of the DOPP program. We attribute this pricing error decrease to the increased trading volume introduced by the DOPP program in this thin market. The interaction term between the DOPP indicator and the option's moneyness was not significantly different from zero in models of either absolute or relative options prices.

An errors-in-variables problem may occur due to the stochastic DOPP volume variable if high DOPP volume relates to the unexplained portion of the DOPP prices. The lack of clearly useful instrumental variables for DOPP volume led us to alternatively estimate each of the regression models using a one-period lag of the DOPP volume variable in place of the DOPP volume variable. The estimation results for levels were robust to this alternative formulation in both a qualitative and a quantitative sense. There was little change in the estimation results for the other variables, and the coefficient on the lagged DOPP volume remained significant and negative. One qualitative difference did arise in the alternative specification that uses the lagged DOPP volume in the put error ratio model (Column B, table 5); the coefficient for the lagged DOPP volume was insignificant in this regression. In general however, the regression results for puts in table 5 and the upcoming results for calls appear to be robust to this potential errors-in-variables problem.

Two of the four largest brokers sold DOPP options at significantly higher prices relative to all other brokers in both the levels and the ratio model, with one broker's fills estimated to be 2.5 cents per cwt. higher and the other estimated to be 3.2 cents per cwt. higher in levels.[9] The interpretation of these broker coefficients requires some care. Brokers may be (1) taking advantage of the options purchasers by filling their put purchases at high prices, (2) giving the purchasers the level of services consistent with the (somewhat lower than the going rate) $30 round-turn fee paid under the DOPP program, or (3) serving their clients' wishes by filling orders quickly.[10]

The manner in which brokers could take advantage of option buyers is somewhat analogous to how real estate brokers hired by a home buyer might devote sales effort.[11] A conscientious broker may work hard to negotiate the lowest price for their client; in the options market this hard work might take the form of a set price, rather than an at-the-market order. Some brokers may not be so conscientious, perhaps most likely if their client is inexperienced, and may thus take advantage of the client by devoting less effort to buying the product at the lowest price. Indeed, a conversation with an options broker who participated extensively in the DOPP program stated that at-the-market orders are quite risky in such a thin market as they might be quite expensive (Lough 2006). This broker noted that in order for his DOPP trades to be filled in a reasonable amount of time, he would use set-price orders "giving the seller a few additional cents" (at somewhat higher prices than the going rate) in order to fill the order quickly.

If a buyer is to pay only a fraction of the cost of the product (be it an option or a house), speed of order fill is paramount. Although our data set does not provide information on the time required for order fills, or broker effort, we can observe the differences between the actual and the predicted options prices for DOPP and non-DOPP puts. We explore these alternatives explanations below through consideration of another dependent variable below.

Coefficients for the non-DOPP measures in table 5 are informative. Higher daily volume in the put markets significantly decreases the option's price error, while total option volume (puts and calls) increases this price error. Both general option volume effects are small in economic terms, however. The higher the option's moneyness (the less out-of-the money or the more in-the-money) and its square, the lower is the option's price in levels (this effect decreases at an increasing rate in ratios). The option's price is larger as the difference between the most recent futures price and its previous day's close increases. This estimated effect reflects either market volatility, errors in the Black-Scholes' pricing formula, or market thinness. The larger the option's days to maturity measure, the lower is the pricing difference, perhaps reflecting market thinness for options with considerable time value.

What's Behind the Significant Broker Effects? If the large brokers were taking advantage of their clients by filling DOPP put purchases at too high a price, these brokers would be expected to lose market share, reducing broker effects over time. The percentage of DOPP trades handled by the "most expensive" brokers, 91 and 98, generally increased over time, however, consistent with the notion that options buyers were receiving some type of benefit from using these brokers. Additional non-reported regression estimates showed the broker effects in table 5 to significantly increase over time.

Some additional data allows identification of the nature of the "overpricing" by some brokers. The DOPP data allows us to consider which of the producers are repeat customers of a broker. For the set of trades for which producers who had one or more previous DOPP trades, this binary variable is given the value 1 if the producers used their previous broker for the current order, and 0 otherwise (if they switched brokers). There were 604 DOPP trades observed where producers had at least one previous DOPP trade. Virtually all customers remained with the same broker (there were 22 trades where the broker was replaced), itself an interesting statistic. We estimated a probit model for this binary variable using three primary explanatory variables and an interaction term. One variable is the producer's average error history (unweighted by trade volume) over all trades with the broker, a measure of broker performance. A second variable is the number of DOPP rounds the producer had previously participated in. This variable corrects for learning/experience and to some extent measures differences in producers' opportunities to switch.[12] A third variable is the producer's previous volume traded under DOPP. An interaction term of the average broker error history variable multiplied by the previous rounds variable is also included.

To the extent that the broker effects in table 5 stem from brokers taking advantage of producers and filling put purchases at a high price, the average error history variable and the interaction variable of this average error and previous rounds are predicted to be negative. If instead brokers are generally providing services consistent with the relatively small subsidized brokerage fee of $30 per round turn (set administratively under DOPP), or if they are providing producers quick order fills under these producers' reduced incentives to have low cost options, then these two variables should be positive. The previous trade volume variable is also expected to have a negative coefficient if producers are being taken advantage of by brokers since larger DOPP users have a greater incentive to switch from these brokers. This variable's sign is expected to be positive if brokers are supplying acceptable service. The expected sign for the previous rounds variable should be negative as it measures increases in producers' opportunities to switch brokers as they participate in more DOPP rounds.

The results in table 6 support the argument that brokers are by and large providing the level of service expected by producers, such as through quick order fills. The average error history*previous rounds interaction term is significant and positive, implying that more experienced producers are *more* likely to repeat as a customer if the options price history has been high. The previous trade volume variable is positive and is consistent with its interpretation as measuring variations in producers' opportunity to switch brokers. The previous rounds variable is significant and negative, as hypothesized.

Pricing Differences for Calls

Regression results for the call price errors in levels (Column A) and relative differences (Column B) models for calls are presented in table 7. The lagged dependent variable was significant for up to four periods for levels and ratios. All coefficients on the lagged terms summed to less than one and were monotonically decreasing in both models.

The increase volume of trading for puts under this DOPP program had positive statistical effects on this thin call market when absolute differences were considered, but not for relative differences. We attribute this larger absolute value of the coefficient of DOPP volume on call error to the put-call parity relationship that preserves prices for puts and calls through a risk-free arbitrage (see Hull 2001).

Coefficient estimates on the moneyness and moneyness squared terms are consistent with a significant volatility smile for both absolute and relative options price differences. 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, significantly so for absolute differences. Longer time 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 variables for calls and for combined options trades were insignificant.[13]

Conclusions

This paper evaluates the impact of the subsidized Dairy Options Pilot Program (DOPP) on the underlying options market. DOPP was designed as an educational tool to increase dairy farmers' knowledge of options markets with an eye on reducing producer reliance on administratively set price protection policies. Such subsidized purchase programs have also been touted as having the potential to improve overall options market performance (options pricing efficiency) through increased trading volume. We test this market improvement effect and found statistically and economically significant reductions in options prices as the volume of subsidized options trades increased. Interestingly, there is evidence of this positive market effect for both puts (subsidized and non-subsidized) and calls.

We find that DOPP options purchases were expensive relative to these options' theoretical prices. 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 large brokers filling DOPP orders at relatively high prices.

Additional binary choice regression results evaluating the likelihood that a producer is a repeat customer of a broker allow us to identify whether (1) brokers are in some sense taking advantage of dairy producers under DOPP, or (2) brokers are providing reasonable services such as quick order fills. Note that producers using the DOPP program pay only one-fifth of the option's premium. These probit results support the hypothesis that brokers are providing services desired by producers, even though the resulting options prices appear to be relatively expensive.

The estimated effects of this DOPP program on the options market have broader implications. Dairy producers who used DOPP, and the market generally, benefited from the program. These estimated effects appear at first glance to be modest, with non-DOPP put option price reductions of just under \$.18/cwt and call option price reductions of just over \$.16 per cwt at mean daily DOPP volumes.[14] Each option contract, however, is over 200,000 lbs. of milk, so these estimated average effects *per contract* are \$354.64 for each put option and \$322.66 for each call option. Given the average daily contract volumes during the DOPP period of 54.6 contracts for puts and 51.8 contracts for calls, these estimated DOPP option price reductions are

$19,363 per day for puts and $16,714 per day for calls. Using a 250 day trading year, these estimated annual options price reductions are over $4.8 million for puts and over $4.1 million for calls. Note also that these estimated benefits are not explained by the DOPP program's requirements that only out-of-the-money options be purchased; our use of the differences between actual options prices and their estimates under the Black-Scholes assumptions accounts for the option's moneyness.

Although options sellers are estimated to have experienced a reduction in per contract prices, these market benefits to options buyers are interesting in light of the DOPP program costs of $5 million. At least for the dairy options market for the time period considered, the subsidized options purchased through the DOPP program appeared to have reduced options prices generally, in a sense improving the performance of this options market.

Endnotes

[1] Cheddar cheese and nonfat dry milk futures and corresponding options contracts had previously been listed for trading at the NYBOT in June 1993. Futures and options contracts for butter on the NYBOT began trading in mid-October 1996.

[2] 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.

[3] The CME added a Class IV contract in July 2000 in response to industry interest for a contract more closely related to butterfat price risk. This Class IV contract continues to trade.

[4] These and other pilot programs were permitted under Section 191 of the Federal Agricultural Improvement and Reform Act (FAIR), the 1996 Farm Act [see Vandeveer, et al. 2004)]

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

[6] "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 2001; Campbell, Lo, and MacKinlay 1997; Lough 2006).

[7] It is unlikely given the self-policing mechanism of the exchange, and the potential for entry, that these broker effects would be the result of a collusive agreement between them. Such collusion would be particularly unlikely to impact options trades since the most fitting oligopoly model is a Bertrand price competition model (see Carlton and Perloff 1994).

[8] 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.

[9] Two of the four brokers had significantly lower prices in the ratio model.

[10] Note that the option buyer could pay the broker more than the $30 round turn subsidy provided under DOPP.

[11] Our thanks to Gary Brester for this analogy.

[12] Note that there were multiple cases of producers switching brokers within a DOPP round.

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

[14] These estimates for the levels model were calculated by multiplying the coefficient estimate (-.044) by the average DOPP volume (4.03) for the put market, with a comparable procedure used for calls.

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Table 1. Dairy option pilot program 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 2a. Intra-day options error averages, all rounds: January 1999 – October 2002. Prices in cents per cwt.

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

t-statistics in all tables test the difference of the coefficient from 0.

Table 2b: Intra-day options error averages during Round 1: January 20, 1999 – June 23, 1999.

Prices in cents per cwt.

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 2c. Intra-day options error averages during Round 2: May 12, 1999 – January 23, 2001.

Prices in cents per cwt.

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 2d. Intra-day options error averages during Round 3: March 30, 2001 – January 17, 2002.

Prices in cents per cwt.

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	1,645	-1.90
Calls	-1.78	0.271	902	-6.57

Table 2e. Intra-day options error averages during Round 4: May 22, 2002 – October 31, 2002.

Prices in cents per cwt.

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 3. Mean option pricing error in cents per cwt. for brokers selling under the dairy option pilot program.

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

Bold entries indicate the top four brokers by DOPP volume

Table 4a. Descriptive statistics, put option pricing error 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 4b. Descriptive statistics, call option pricing error 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 5. Actual/predicted options pricing errors for fluid milk put options. Heterosdasticity corrected linear regression with dependent variable lags.

	A: Differences in Levels	B: Differences in Ratios
Constant	-.252	-.040***
	(.184)	(.009)
DOPP INDICATOR	5.01***	.109***
	(.447)	(.008)
DOPP VOLUME	-.044***	-.7E-03**
	(.009)	(.3E-03)
DOPP*MONEYNESS	.021	.4E-04
	(.019)	(.3E-03)
MONEYNESS	-.008***	-.2E-03***
	(.001)	(.3E-04)
MONEYNESS SQUARED	-.10E-04*	.1E-05***
	(.5E-05)	(.2E-06)
PUT OPTION VOLUME	-.08***	-.3E-03***
	(.2E-02)	(.1E-03)
TOTAL OPTION VOLUME	.005***	.2E-03**
	(.002)	(.7E-04)
DAYS TO MATURITY	-.003***	.8E-04*
	(.001)	(.5E-04)

FUTURES PRICE CHANGE	.069***	.002***
	(.011)	.3E-03
BROKER 91 INDICATOR	2.47***	.02***
	(.420)	.7E-02
BROKER 94 INDICATOR	.285	-.02**
	(.429)	(.007)
BROKER 98 INDICATOR	3.17***	.02***
	(.49)	(.8E-02)
BROKER 110 INDICATOR	-.530	-.03***
	(.412)	(.7E-02)
Lagged Error (-1)	.271 (.027)	.155 (.024)
(-2)	.166(.022)	.075 (.017)
(-3)	.086 (.018)	.058 (.013)
(-4)	.074 (.022)	.043 (.014)
(-5)		.021 (.012)
	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. (Standard Errors)

Table 6. Probit model for repeat customers (1 if a repeat, 0 otherwise). N=604.

Constant	1.65***
	(.197)
Producer's Average Error History with Broker	-.006
	(.024)
Producer's Previous Rounds	-1.29***
	(.264)
Producer's Previous DOPP Trade Volume	.046***
	(.014)
Average Error History*Producer's Previous Rounds	.157***
	(.057)

*** significance at the 1% level. (Standard Errors). Model log-likelihood -33.96, chi-squared (4 df) 49.89.

Table 7. Actual/predicted options pricing errors for fluid milk call options. Heteroscedasticity corrected linear regression with dependent variable lags.

	A: Differences in Levels	**B: Differences in Ratios**
Constant	-1.72***	-.155***
	(.224)	(.019)
DOPP VOLUME	-.073***	-.16E-02
	(.020)	(.12E-02)
MONEYNESS	-.008***	-.3E-04
	(.001)	(.8E-04)
MONEYNESS SQUARED	.2E-04***	.2E-05***
	(.5E-05)	(.4E-06)
CALL OPTION VOLUME	.002	-.1E-03
	(.3E-02)	(.2E-03)
TOTAL OPTION VOLUME	.7E-03	.8E-04
	(.002)	(.1E-03)
DAYS TO MATURITY	.006***	.7E-03***
	(.001)	(.1E-03)
CHANGE IN THE FUTURES PRICE	-.034**	-.9E-03
	(.013)	.8E-03
Lagged Error (-1)	.209 (.016)	.155 (.033)

(-2)	.076 (.016)	.075 (.017)
(-3)	.060 (.016)	.058 (.020)
(-4)	.049 (.016)	.043 (.020)
	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. (Standard Errors).