Market Makers in Options Markets: An Investigation of the NYMEX Natural Gas Market

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Abstract

I evaluate the institution details of competitive market maker behavior in the natural gas futures options and futures markets in order to determine the characteristics of traders subsuming the market making role in these markets. I also decompose option portfolio risk for options market makers by evaluating their intraday and end of day risk holdings. The premise that market makers in futures options markets strategically manage their exposure to volatility (vega) while using futures to offset exposure to changes in the underlying price (delta) is examined.

I. Introduction

O'Hara (1995) describes that the rules of a market determine its trading mechanism; this includes what can be traded, who can trade, when and how orders are submitted, how the orders are processed, and how prices are set. These rules play a particularly dominant role for trading in the futures and futures options markets due to the lack of a designated market maker. Limited research has been conducted which has established that member proprietary trading serves the market maker function in futures markets (Kuserk and Locke, 1993 and 1994); much less research has focused on the market maker role in options markets. I add to the literature base on markets dominated by competitive market making structures through a comprehensive examination of the market making role in options markets, as well as a direct comparison to the corresponding futures market, using trader-level, transactions data from the NYMEX natural gas markets.

Futures and futures options markets have similar underlying structures. Their trading takes place through both open outcry and electronic trading[1] within the framework of an organized auction market. Floor traders in both markets can be categorized as trading for their own account, their clearing firm's account, another floor trader, or a non-member customer (CTI 1, 2, 3, and 4 respectively). Trader income comes from speculative trading, brokerage, and/or commissions.

Although futures and options markets both function under a competitive market making structure, traders in these markets differ primarily with respect to their risk levels as futures contracts represent an obligation to perform while options contracts offer the ability to perform. This may lead to differences in the market making function of traders in options markets versus those in futures markets. It has previously been shown that market makers in futures markets are

[1] NYMEX options are not traded electronically. NYMEX futures began electronic trading in September 2006.

characterized by their low end-of-day inventory holdings, small trades, and large volumes (Kuserk and Locke, 1993). The analysis here will investigate whether those characteristics universally hold in the natural gas futures market, as well as if any differences exist in these characteristics for options market makers in order to confirm the existence, and examine the dynamics, of market making in the options market.

Due to the construction of the futures and options markets, it is not easy to deconstruct the price formation mechanism. The price formation process is a determination of who is setting the prices and an investigation of the impact of various market frictions on the price discovery process. Deconstruction of the option market making function in the natural gas market is key to evaluating their ability to provide liquidity and price discovery.

Once a subset of traders has been identified as exhibiting market making behavior in the options market, it is of further interest to evaluate how their trades impact market dynamics. Several researchers have postulated that market makers hedge inventory risk exposures by maintaining delta-neutral positions (Figlewski, 1989; Cox and Rubinstein, 1985). As such, it is thought that option market makers engage in hedging by (for example) purchasing a quantity of futures options while simultaneously executing a certain number of contracts in the underlying futures contract, seeking instantaneous delta neutrality. The degree to which these traders hedge by participating in both markets will determine their vulnerability to the risk of holding positions in the option market, which should affect the prices at which they are willing to trade. The short run exposure of the futures options market maker to delta is expected to be small if they are instantaneously delta-hedged, while the exposure to volatility, vega, may more accurately represent the "inventory" that the market maker is carrying. To examine this premise, options market makers risk, as measured by delta, gamma, and vega, is evaluated over the course of each trading day.

The remainder of this paper proceeds as follows: Section II provides information about the data and summary statistics; Section III investigates the behavior of market makers in options markets, with direct comparison to the corresponding futures market; Section IV analyzes market maker risk in the options market; Section V concludes.

II. Data

The data for this research consist of twenty months of transactions level data in the natural gas futures and options markets traded on NYMEX which spans September, 2005 through April, 2007. This dataset is maintained by the U.S. Commodity Futures Trading Commission and comes from the computerized trade reconstruction (CTR) records compiled and maintained by the agency from data feeds from the exchanges.

The data include records of all open outcry trades, and provide information including the price, quantity of the trade, trade date, trade time to the second, trade direction (buy or sell), delivery month and year of the contract, customer type (trade for the member's account, his house's account, another member on the floor, or a customer), counterparty's customer type, and the floor trader's identification. The data taken after September 2006 also contain electronic trader data for the futures market.

The trading time for the open outcry natural gas pits is from 9:00 am to 2:30 pm (ET). The futures contracts trade in units of 10,000 British thermal units (mmBtu) and require physical settlement. The minimum price fluctuation is $0.001 per mmBtu, or $10 per contract, while the maximum is $3.00 per mmBtu, or $30,000 per contract.

Delivery is conducted through the Sabine Pipe Line Company, Henry Hub in Louisiana and can take place no earlier than the first calendar day of the delivery month and no later than the last calendar day of the delivery month. The Henry Hub is the nexus of sixteen intra- and interstate natural gas pipeline systems that serve markets throughout the U.S. East coast, the Gulf coast, the Midwest, and up to the Canadian border. The seller is responsible for the movement of the gas through the Hub and pays all Hub fees, while the buyer is responsible for movement from the Hub.

This data contains information on both options and futures trades. A call option, when exercised, turns into a long futures contract, while a put option is transformed into a short futures contract when exercised. The volatility in natural gas futures prices makes futures and futures options an attractive trading venue for speculators. These markets are also used by a wide variety of companies, from those involved in exploration and the production of natural gas to substantial end-users of natural gas to hedge their price risk. In the U.S. natural gas market, price peaks and troughs over a market cycle are cyclical, highly dependent upon weather conditions with warmer weather driving prices down and colder weather leading to increases. [2]

III. Market Making Behavior in Options Markets

Due to the open design of futures and futures options markets, designated market makers do not exist. It is important to uncover those who subsume the market making role in order to evaluate the dynamics of the price setting function in futures, options, and other similar, markets. Limited research in futures markets suggests that traders known as scalpers can be identified who behave like market makers in that they buy and sell often and in small quantities, and, as such, provide liquidity to the market. Working (1967, 1977) finds that traders identifying themselves

[2] Although seasonal patterns do exist in natural gas prices, I will not control for them here due to the fact that I am utilizing the underlying futures contracts as a means of comparison. In other words, the relationship between the futures and futures options market should not be seasonal.

as scalpers make their income from frequent buys at the bid followed by a sell at the ask after a favorable price change, which is consistent with market maker behavior. Silber (1984) examines the trading activities of one scalper working on the New York Futures Exchange and finds that success in scalping activities involves frequent trading, in small quantities, with little inventory accumulation. Kuserk and Locke (1993, 1994) also examine scalper behavior and find that they earn income which differs across commodities and is correlated with the range of income from other traders.

Analysis of market making dynamics in options markets has received even less attention. Jameson and Wilhelm (1992) evaluate the risks that options market makers face, and provide empirical evidence that their risk factors are unique to option markets due to the stochastic volatility of the option return. Specifically, by measuring the impact of delta, gamma, and vega on bid-ask spread, they find that gamma and vega are significant determinants of spreads. Giannetti, Zhong and Wu (2004) develop an inventory based approach to study the market making behavior in options markets. They posit that the hedging practices of options market makers have a substantial impact on the setting of bid ask spreads and in setting optimal inventory control. By adding hedging mechanisms to the standard inventory control model, the authors derive the market makers optimum option quote setting and inventory control policies.

Participation in futures options allows traders to benefit from favorable market moves, while mitigating their downside risk due to adverse market conditions. The holder of a long call option contract is limited to downside losses only by the amount paid for the premium, while holding the ability to realize unlimited upside gains. These gains are the same as would have been achieved if the trader had held the long futures position established at that strike price less the original premium paid for the option. Thus, the ability to participate in favorable market moves through futures markets is available with a known cost of price protection.

Based on the previous research by Working (1967, 1977), Silber (1984), and Kuserk and Locke (1993, 1994) the hypothesis is tested that member proprietary traders, also known as CTI 1 traders or those who trade for their own accounts, take on the role of market makers within the competitive framework of an options market. To determine the positions and identify the levels of market making activity, several different measures are evaluated. The average daily number of trades, volume, trade size, and time between trades are examined in order to gauge contract activity rates and levels, as well as to provide information about market maker's daily trading patterns. Average daily inventory is evaluated to determine the risk and exposure of option market makers to overnight volatility. Each of these are analyses are performed across all four trader categories and the nearby, first deferred, and second deferred contract expirations.

Information on the total and average number of trades per day, total and average volume, average trade size, and average time between trades can be found in Table 1.a. and Table 1.b. for the options and futures markets respectively. The statistics were performed in monthly batches, which were then aggregated over the twenty months in the sample period for all four trader categories and the three nearest expirations.

Table 1.a indicates that CTI 1 traders, or those who trade for their own accounts, present the highest levels of trading in both the nearby and first deferred contracts with levels that are almost twice the number of trades of the next highest trader category (CTI 4). In the second deferred contract, CTI 3 (those who trade for a customer) traders have the highest daily average number of trades at 161 and total number of trades at 92,585 versus 157 daily average number of trades and 90,543 total number of trades for CTI 1 traders. The nearby and first deferred

contracts are typically the most actively traded contracts, and, as such, should have the greatest impact on prevailing market prices and trading behavior.

Table 1.a also presents information on the daily average and total volume for each of the traders groups across the three nearest expirations. The volume numbers indicate that while CTI 1 traders are trading more frequently than their other trader counterparts, their average volumes do not exceed the next highest trader category by a significant order of magnitude. This is in line with the previous research on market making in futures markets which found that market makers tend to trade in small amounts. Table 2.a. and 2.b. provide information on the percentage of total volume handled by the top ten percent of traders. This data imply that trading in the options market is much more concentrated than that in the futures market with over 50% of the overall volume handled by only ten traders in the options market versus approximately one-fifth in the futures market. Trading in the further to expiration contracts indicate a similar pattern.

The average trade size numbers further support the notion that market makers tend to trade in small amounts with the average trade size for CTI 1 traders being almost three times lower than any other trader category at 38.22 versus 90.50, 95.08, and 118.34 for CTI 2, 3, and 4 traders respectively. As expected, the participation in the first and second deferred contract is much less in terms of the number of trades and the volume of trades. It is of interest to note that the average trade size for the second deferred contract is much larger across all trader categories indicating that trading in further out contracts may be due to temporary disequilibrium in prices and that these traders are attempting to maximize their profits due to market frictions.

The daily average time between trades is not significantly different for each trader group. The time between trades shows a monotonic decline in the further to expiration contracts. Thus, although the levels of activity in terms of volume are higher in the nearby contract, the time between trades is actually longer.

Evaluation of the trading activity of natural gas futures traders in Table 1.b. paints a similar picture. The CTI 1 traders dominate the market in terms of their participation levels. Trading in the futures markets takes place on a much lower per trader level than the options market with the highest number of trades averaging at about 89 for CTI 1 traders and the daily average volume at 13,352 trades per day on average. The average trade size for CTI 1 traders is still the smallest, however the relative difference between CTI 1 traders and other traders groups narrows in the futures market. Similar findings were also shown for the daily average time between trades for the options and futures markets, with a monotonic decline in the first and second deferred contracts. As expected, trading in the futures market occurs on a much more frequent basis than that of the options market as shown from the much smaller time in between trades across all trader groups and contract expirations.

Table 3.a. and 3.b. provide the average daily ending inventory levels for all trader groups and the three nearest to expiration contracts. CTI 1 option traders have the smallest levels of average ending inventory in the nearby and first deferred contracts and the second to smallest level in the second deferred contract. On average, CTI 2 traders tend to be long and CTI 4 traders tend to be short at the end of the trading day. CTI 2 traders hold the largest amounts of inventory overnight. Similar results are found in the futures market, except there do not appear to be any trends as to the preferences of certain trader groups being net long or short at the end of the trading day. This provides evidence that futures option and futures market makers try to mitigate their exposure to unexpected information that may accumulate overnight by ending the trading day with very low levels of inventory accretion.

Daily income levels were also calculated for each trader group and contract expiration with the results presented in Table 4.a. and 4.b. On average market making in options markets is unprofitable as measured by both the mean and median levels of income for personal traders; however, market making in the further to expiration contracts becomes profitable for this trader group. This indicates that market makers may be providing a liquidity service in the nearby contract while using the less liquid contracts to make the majority of their profits. Why these traders are providing this service without due compensation does not fall under the risk-return tradeoff of rational investor behavior and warrants further investigation. A reasonable explanation for the lack of profitability in the options market may be due to asymmetry in income levels among traders; there may be a few traders losing large sums while the vast majority earns positive income. On the other hand, market making in futures markets appears to be profitable. Customer initiated trades are also not profitable across all contract expirations in both options and futures market, while those that are initiated by the brokerage house earn the highest levels of income in all but the first deferred contract.

Overall, the above analysis supports previous literature that has found that member proprietary, or CTI 1, traders are those who subsume the market making role in futures markets and extends this to the option market. On average, market makers in the option market trade often, in small amounts, with very little time in between trades, and are responsible for the highest levels of activity in terms of volume. They also end the trading day with very low levels of inventory in order to mitigate their exposure to overnight inventory holding risk. Evaluation of the extent of competitive forces in each trader group and the use of interdealer trades to expel unwanted inventory quickly follows and is conducted in order to provide more information on the institutional details of option market making.

III.b. Options and Futures Market Making: A Competition Based System

Futures and options markets operate under a competitive market making system, which is in stark contrast to the designated system of the NYSE specialist. In general, competition among dealers has been found to lower spreads (Stoll, 1978; Benston and Hagerman, 1974; Tinic and West, 1972, Wahal, 1997; Klock and McCormick, 1999). Understanding the dynamics of the price formation process requires an evaluation of the competitive forces among market makers, which includes why and how bid-ask spreads exist and are formed, as well as the impact of competition among market makers.

Tinic (1972) finds that spreads are actually lower when there is greater competition from other markets, while Tinic and West (1972) find that spreads are lower when there are multiple dealers present. Benston and Hagerman (1974) were among the first to evaluate the relationship between the number of market makers and bid-ask spreads finding that a negative relationship between the number of market makers and spreads exists. Stoll (1978) has a similar conclusion in his paper analyzing the factors that determine the price of dealer services, as well as the optimal number of dealers willing to make a market in a stock using end of day data from the NASDAQ, OTC market. Wahal (1997) examines the determinants, frequency, and impact of entry and exit of market makers for stocks on the NNM, and shows that the number of dealers in a security is a function of trading intensity, volatility, and the bid-ask spread. Consistent with the competitive model of dealer pricing, market entry is associated with declines in bid-ask spreads. Klock and McCormick (1999) provide a more recent view of market maker competition in the NASDAQ OTC market. Similar to that of Wahal (1997) and others, they find that a negative relationship exists between the number of market makers and spread. Further, this relationship is nonlinear with a decreasing impact by the marginal market maker.

While the emphasis here is not on the proportion of bid-ask spread attributable to competition, the number of brokers is examined across markets and trader and contract type to determine the extent of competitive forces in each of the various trader categories. The results in Table 5.a. (5.b) indicate that CTI 4 and CTI 1 traders have the greatest amounts of individual participation holding 53% (55%) and 39% (34.5%) respectively of the overall participation in option (futures) market. There are very few CTI 2 and CTI 3 brokers who participate in either options or futures trading. Further, as anticipated, the nearby contract has the highest percentage of brokers at 46.5% (51%) of the overall. These results indicate that based on the competitive model of dealer pricing, spreads for the CTI 1 and CTI 4 traders should be lower, on average, than those for CTI 2 and CTI 3 traders.

III.c. Inventory Control

The inventory control models of market microstructure assume that market makers face exogenous demands to buy and sell, and that these market makers earn profits from buying and selling at the bid and ask prices respectively. The models predict that market makers will manage their risks and control inventory levels by adjusting the bid and ask prices to induce buying or selling to bring inventory levels into a preferred range. A line of literature has evaluated the dynamics of multiple dealer markets and inventory control mechanisms.

Ho and Stoll (1983) consider markets with several dealers and stocks over several periods to develop a theoretical model of equilibrium in a market with competing dealers which provides an empirical basis for the comparison of competing and monopolistic dealer markets. Dealers face risk which stems both from uncertainty about the returns on their inventories as well as the arrival of transactions. Each dealer also recognizes that his welfare depends on the actions of other dealers and works to maximize his expected utility of wealth when setting prices.

Hansch, Naik, and Viswanathan (1998) test the implications of Ho and Stoll (1983) that inventory differences determine dealer behavior. They find that relative inventories explain which dealers obtain large trades and that movements between best bid, best ask, and straddle are highly correlated with inventory changes. They further find that interdealer trading plays a large role in managing large inventory positions with a key determinant of variations in interdealer trades being inventory levels.

Reiss and Werner (1998) use data from the London Stock Exchange to test whether interdealer trade facilitates inventory risk sharing among dealers. Their main focus is on whether dealers primarily use interdealer trades to reduce their inventory exposure, which they find to be the case. In fact, interdealer counterparties most often have the most extreme inventory imbalances. Manaster and Mann (1996) evaluate the cross section relationship between market maker inventory positions and trade activity using futures transactions data. They find that not only do traders control inventory throughout the day, they also find a strong positive correlation between inventory and reservation price with increases in inventory leading to higher prices. Lyons (1995) also provides evidence suggesting that market makers set their prices as a function of inventory levels. Locke and Sarajoti (2004) find that dealers use interdealer trading as a management tool to control their inventory positions. In fact they find that dealers are more likely to use interdealer trades, rather than customer trades, to reduce their inventory positions.

I analyze the percentage of trades occurring within each trader category and present the findings in Table 6.a. and 6.b. for options and futures trades respectively in order to evaluate whether dealers may be using interdealer trades to reduce their inventory positions. As discussed in Locke and Sarajoti (2004) interdealer trades are typically more costly to initiate than trades conducted with other trader groups, thus the only rational explanation for the existence of a significant percentage of interdealer trades is inventory control; these traders would rather immediately transfer their unwanted inventory than face the uncertainty of waiting for customer orders. Member proprietary traders are counterparties in 94.88% of the trades in the options market versus 40.07% in the futures market. The levels of interdealer trades across contract expirations for the option market are decreasing in expiration, but are not significantly different. They subsume a substantial amount of the overall trading activity (22.82%, 17.82%, and 16.33% in the nearby, first deferred, and second deferred contracts respectively) lending support to the notion that interdealer trades are used by market makers for inventory control purposes. In the futures market, the highest percentage of interdealer trades occurs in the first deferred contract at 15.39%, while the next highest is in the second deferred contract. This provides evidence that market makers in the futures markets are using interdealer trades to control their inventory levels in the less liquid contract markets.

IV. Option Market Makers Risk Exposure

To determine option market makers exposure to risk, inventory positions must be examined in terms of a vector of risk measures, which include delta, gamma, and vega. Delta measures the degree to which an option price will move given a change in the underlying asset, or, in this case, the sensitivity of the option to the futures price. The delta is often called the neutral hedge ratio; if you have a portfolio of n shares of a stock then n divided by delta gives you the number of calls you would need to write to create a neutral hedge.

Gamma provides you with how much the delta changes for a $1.00 change in the stock price. It is the second partial derivative of the option price with respect to the underlier. If gamma is small, delta changes slowly, and to keep a portfolio of options delta neutral one can rebalance their portfolio less frequently. If gamma is large, delta is extremely sensitive to changes in the underlying price, and, as such, the portfolio will have to be adjusted more frequently.

The vega of an option indicates how much the price of the option will change as the volatility of the underlying asset changes. Vega is calculated to show the theoretical price change for every 1% point change in implied volatility. Vega is the greek which has the most impact on option prices second to delta. Jameson and Wilhelm (1992) showed that an options gamma and vega were important in the determination of option market makers bid-ask spreads and provided an indication of the inventory risk exposure these traders faced.

The risk characteristic (delta, vega, etc.) of a portfolio of options can be described by the sum of the risk characteristics of the portfolio components. If the assumption of instantaneous delta hedging in the futures market holds true, market makers in futures options markets may work to strategically manage the portfolio vega, while allowing the option portfolio delta to fluctuate over the course of the trading day.

Of critical importance to the evaluation of the risk characteristic which provides the most information about exposure to inventory holding risk is whether market markers in option markets maintain delta neutrality by hedging their trades in the options market with offsetting positions in the underlying futures market or by forming a delta neutral portfolio using related options. While many have speculated this to be the case, no one has been able to reliably track trades from the options market to the futures market or within the options market. This unique dataset facilitates the evaluation of traders' positions in both the futures and options markets, which allows for incorporation of information about whether these traders are maintaining delta neutral positions by conducting simultaneous, off-setting trading.

IV.a. End-of-Day Analysis

As a first pass approach to evaluating the risk characteristics of market makers in options markets, I evaluate their end-of-day position risk parameters. Evaluation of the end of day positions allow for an examination of the extent to which market makers in the options market work to mitigate exposure to overnight price and volatility risk. A binomial pricing model is used to estimate the option premiums and futures prices, which allows for the early exercise component of futures contracts, and an implied standard deviation is used as a proxy for σ_F. This implied standard deviation is calculated from the most actively traded, near-the-money call option for the nearby underlying futures contract similar to Jameson and Wilhelm (1992). However, here a grid search is used to find the implied standard deviation which minimizes the mean-squared-error over the trading day by comparing the average option premium to the observed premium for each hypothetical sigma. The average volatility for both bid and ask prices each day is evaluated to ensure that the range sufficiently covers all possible values in order to avoid corner solutions. It is well known that option valuations cycle from high to low as the number of steps increases, holding time to maturity constant. Therefore, I use two separate steps, 30 and 31, to calculate the average option value for each hypothetical sigma.

Once the premiums, futures prices, and implied standard deviation have been found, the delta, gamma, and vega are calculated as in Hull (2000). Position delta, gamma, and vega are then obtained for each trader in each trading day in the sample. If a trader is simultaneously trading in both the options and futures markets, position delta will reflect the extent to which the trader is maintaining a delta neutral portfolio at the end of each day by creating offsetting trades from participation in both markets. If the trader is only participating in the options market, the position delta will be calculated using only the trades from the options market and will also provide information about end of day delta neutrality. The gamma and vega of the underlier are zero, and, as such, those values only incorporate information about trades in the option market.

Table 7 gives information about the mean and median values of end-of-day position delta, gamma, and vega aggregated over all 20 months in the sample. The median value of all of the risk parameters are zero, and the mean values are very small in relative terms. Position gamma is positive on average, indicating that traders do not need to rebalance their portfolio very often in order to mitigate their risk to changes in the price of the underlier. This also addresses concerns that the discrete rebalancing option market makers are exposed to increases their overall price risk; while this may be more of an issue intraday, over the course of any one day this concern is alleviated. Position vega is negative on average, which means that the average position will gain as volatility falls. Overall, it appears that market makers in option markets reduce their exposure to overnight price and volatility risk by ensuring that their end of day values are very small. To test for the use of simultaneous trading in the option and underlying futures market, position delta was also calculated using only trades in the options market. The mean value was significantly higher at 5.77, thus providing support to the notion that some market makers utilize the futures markets to maintain delta neutral positions.

IV.b. Intraday Analysis

Of further importance is whether and how the market maker's inventory holding risks are changing over the course of the trading day. Examining the intraday, as well as, the end-of day values of delta, gamma, and vega, will allow for a decomposition of the characteristics that option market makers manage in order to mitigate their exposure to inventory risk. By evaluating the distribution of the risk characteristics over the trading day, one will be able to determine whether any intraday patterns in risk management exist for market makers in the options market. Intraday analysis will also allow for a determination of whether instantaneous, rather than end-of-day, delta neutrality exists.

My first approach to studying the intraday risk holdings of market makers in the options market is to evaluate their positions at midday. Delta, vega, and gamma are calculated using the daily implied standard deviations that were found in the end-of-day analysis. The market makers position delta, gamma, and vega are calculated by aggregating their trades over the time period spanning 9:00 am until 12:00 pm and compared to the end of day positions.

Position delta is slightly higher midday than end-of-day at 2.17 versus 0.23, lending minor support to the hypothesis that market makers allow fluctuation in their portfolio delta due to maintaining delta neutral positions. Gamma is also larger in absolute terms indicating that intraday, delta changes more quickly and market makers must rebalance their portfolios more often in order to maintain delta neutral positions. Position vega on the other hand, is smaller in absolute terms, which may be due to the intraday maintenance of market makers exposure to volatility risk.

These conclusions must be further explored by studying intraday market maker risk over smaller time increments. Therefore, I also evaluate market maker risk over five time increments as shown in Table 9. Two trends are revealed from this analysis. First, delta is monotonically increasing over the course of an average trading day; exposure to price risk is higher at the end of the day than at open. Second, exposure to volatility risk is very low at the open, increases mid-morning, and then remains relatively constant throughout the rest of the trading day. This provides further support to the mid-day analysis conclusion that market makers are attempting to maintain their exposure to volatility throughout the course of a trading day. Gamma is the largest in the morning trading hours, and dissipates in the afternoon. Thus, concerns of intraday discrete rebalancing are minimal over the course of the trading day.

V. Conclusion

The institutional characteristics of four trader groups are evaluated for the options and futures NYMEX natural gas markets in order to decompose which trader group is taking on the role of a market maker in the options market. It is found that member proprietary traders in the options natural gas market behave as if they are market makers; on average, trading often, in small amounts, with very little time in between trades, and are responsible for the highest levels of activity in terms of volume. They also end the trading day with very low levels of inventory in order to mitigate their exposure to overnight inventory holding risk. Evaluation of the extent of competitive forces in each trader group and the use of interdealer trades to expel unwanted inventory is also conducted in order to provide more information on the institutional details of option market making. It is shown that member proprietary traders are one of the largest trader groups and engage in significant amounts of interdealer trading in order to maintain their preferred inventory levels.

The portfolios of option market makers are examined in terms of their exposure to daily levels of risk as measured by delta, gamma, and vega. It is found that end-of day positions are very small which supports the hypothesis that market makers try to mitigate their exposure to overnight risk. The midday analysis provides higher values of delta and gamma and smaller values of vega providing mild evidence that option market makers work to maintain their exposure to volatility risk. Intraday, delta is shown to increase monotonically, while vega remains relatively constant; lending support to the hypothesis that market makers in options markets work to maintain their exposure to volatility risk while allowing larger fluctuations in price risk due to their ability to offset this exposure by trading in the underlying futures contract.

Rather than aggregating the trades into one hour increments, it would also be beneficial to evaluate changes in risk exposure on a trade-by-trade basis. Therefore, further analysis will be conducted with methodology that will mirror that of the end-of-day analysis; however the implied standard deviation will be found from the most actively traded, near-the-money call option for the nearby underlying futures contract in previous time increment, rather than the futures settlement price. The distribution of each of the risk characteristics will be evaluated over quintiles and time to determine how the market maker's inventory holding risks are changing over the course of the trading day. In order to determine whether instantaneous delta neutrality holds, I will evaluate the five largest traders each day.

Once the behavior of option market makers has been established, future research should evaluate how changes in risk holdings affect the prices that market makers maintain. Patterns in bid-ask spreads are well documented, and, as such, the intraday changes in risk holdings and the movement of traders into and out of the market may serve as additional measures to help explain their U-shaped patterns. Other areas that deserve further examination include why market makers in the option market provide liquidity services if they are earning negative income, as well as the extent to which interdealer trading impacts risk levels, and ultimately market prices. These are largely untouched areas in the literature and warrant further investigation.

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Table 1.a. Summary Statistics for NYMEX Natural Gas Options

Panel A: Nearby Contract

CTI	Daily Average Number of Trades	Total Number of Trades	Daily Average Volume	Total Volume	Average Trade Size	Average Time Between Trades
1	1969	1,136,352	5,232	2,160,672	38.22	20.05
2	179	103,062	613	227,330	90.50	20.21
3	89	51,005	458	177,324	95.08	18.98
4	1082	622,898	4,675	1,930,659	118.34	19.73

Panel B: First Deferred Contract

CTI	Daily Average Number of Trades	Total Number of Trades	Daily Average Volume	Total Volume	Average Trade Size	Average Time Between Trades
1	802	461,583	2,993	1,236,031	42.51	13.18
2	88	50,770	585	189,577	109.67	13.94
3	38	21,693	233	63,144	88.48	12.21
4	496	286,259	3,108	1,283,489	113.19	12.85

Panel C: Second Deferred Contract

CTI	Daily Average Number of Trades	Total Number of Trades	Daily Average Volume	Total Volume	Average Trade Size	Average Time Between Trades
1	157	90,543	1,679	693,520	44.89	8.88
2	91	52,370	399	99,440	113.81	11.31
3	161	92,585	232	43,763	122.79	10.56
4	87	50,333	2,029	838,143	128.95	10.13

Table 1.b. Summary Statistics for NYMEX Natural Gas Futures

Panel A: Nearby Contract

CTI	Daily Average Number of Trades	Total Number of Trades	Daily Average Volume	Total Volume	Average Trade Size	Average Time Between Trades
1	89	146,903	13,352	3,591,645	7.94	2.98
2	5	6,056	1,797	483,409	18.45	3.85
3	4	6,017	628	169,027	10.84	2.35
4	55	90,644	9,363	2,518,702	15.17	4.12

Panel B: First Deferred Contract

CTI	Daily Average Number of Trades	Total Number of Trades	Daily Average Volume	Total Volume	Average Trade Size	Average Time Between Trades
1	47	76,841	7,521	2,023,137	10.07	0.27
2	4	3,458	1,777	478,070	26.73	0.78
3	2	2,005	318	85,605	10.51	0.40
4	33	54,117	6,112	1,644,106	20.73	0.74

Panel C: Second Deferred Contract

CTI	Daily Average Number of Trades	Total Number of Trades	Daily Average Volume	Total Volume	Average Trade Size	Average Time Between Trades
1	26	43,242	3,182	856,016	11.74	0.28
2	3	1,881	1,076	287,270	35.86	0.33
3	2	1,068	150	40,137	14.69	0.08
4	20	32,103	2,727	733,686	25.27	0.41

Table 2.a. Average Daily Volume Handled by Top 10 CTI 1 Options Traders

Contract Type	Average Percent Volume
Nearby	47.05%
First Deferred	27.14%
Second Deferred	15.63%

Table 2.b. Average Daily Volume Handled by Top 10 CTI 1 Futures Traders

Contract Type	Average Percent Volume
Nearby	18.91%
First Deferred	13.89%
Second Deferred	8.11%

Table 3.a Average Daily Ending Inventory for the Options Market

Panel A: Nearby Contract

CTI	Daily Average Ending Inventory
1	-0.85
2	37.43
3	10.70
4	-2.18

Panel B: First Deferred Contract

CTI	Daily Average Ending Inventory
1	-0.33
2	68.45
3	4.04
4	-2.63

Panel C: Second Deferred Contract

CTI	Daily Average Ending Inventory
1	5.05
2	45.30
3	2.72
4	-5.77

Table 3.b Average Daily Ending Inventory for the Futures Market

Panel A: Nearby Contract

CTI	Daily Average Ending Inventory
1	0.92
2	-12.53
3	-1.24
4	0.85

Panel B: First Deferred Contract

CTI	Daily Average Ending Inventory
1	0.22
2	13.67
3	-0.77
4	-1.31

Panel C: Second Deferred Contract

CTI	Daily Average Ending Inventory
1	-0.53
2	21.47
3	0.76
4	-2.55

Table 4.a. Daily Income Levels for Natural Gas Options Traders

Panel A: Nearby Contract

CTI Type	Total Average Income	Minimum	25%	Median	75%	Maximum
1	-42,408	-6,494,048	-993,451	-23,529	863,279	16,700,880
2	3,045,416	-110,379,000	-1,485,390	698,316	5,335,166	230,910,000
3	617,374	-15,757,970	-770,640	140,585	1,743,332	27,729,125
4	-180,553	-15,617,995	-749,090	-53,608	564,773	4,885,047

Panel B: First Deferred Contract

CTI Type	Total Average Income	Minimum	25%	Median	75%	Maximum
1	-7,237	-13,429,218	-1,030,840	107,488	1,089,424	9,725,842
2	3,432,201	-147,140,000	-2,276,844	972,105	7,782,250	171,105,958
3	-217,173	-93,160,510	-1,764,750	-1,088	2,363,283	29,993,960
4	-152,672	-8,394,095	-989,541	-233,478	588,856	15,087,628

Panel C: Second Deferred Contract

CTI Type	Total Average Income	Minimum	25%	Median	75%	Maximum
1	124,997	-14,813,153	-976,624	238,196	1,360,609	20,105,475
2	2,986,422	-254,290,000	-3,079,333	771,900	7,017,500	157,716,000
3	199,238	-51,402,000	-2,378,880	-34,500	3,238,500	57,064,000
4	-290,023	-25,641,226	-1,328,300	-281,002	753,261	13,914,056

Table 4.b. Daily Income Levels for Natural Gas Futures Traders

Panel A: Nearby Contract

CTI Type	Total Average Income	Minimum	25%	Median	75%	Maximum
1	1,045	-64,492	-1,424	629	3,481	63,629
2	2,084	-500,889	-11,796	399	13,184	277,329
3	167	-105,120	-4,823	-76	5,240	68,584
4	-759	-30,721	-2,118	-387	921	21,642

Panel B: First Deferred Contract

CTI Type	Total Average Income	Minimum	25%	Median	75%	Maximum
1	2,054	-27,909	-1,523	1,094	3,764	85,499
2	-5,300	-418,458	-21,385	-1,284	11,188	238,041
3	490	-154,821	-5,334	195	6,132	195,384
4	-485	-48,328	-3,031	-434	2,267	50,882

Panel C: Second Deferred Contract

CTI Type	Total Average Income	Minimum	25%	Median	75%	Maximum
1	1,163	-63,395	-1,924	761	3,835	44,878
2	6,730	-572,000	-16,728	1,320	20,628	1,415,205
3	2,606	-357,997	-8,031	-52	8,954	2,380,200
4	-1,998	-178,295	-5,991	-631	3,150	66,210

Table 5.a. Daily Average Number of Options Brokers

Panel A: Nearby Contract

CTI	Average Number of Brokers
1	28
2	3
3	4
4	43

Panel B: First Deferred

CTI	Average Number of Brokers
1	22
2	2
3	2
4	27

Panel C: Second Deferred

CTI	Average Number of Brokers
1	15
2	1
3	2
4	19

Table 5.b. Daily Average Number of Futures Brokers

Panel A: Nearby Contract

CTI	Average Number of Brokers
1	136
2	24
3	23
4	267

Panel B: First Deferred

CTI	Average Number of Brokers
1	107
2	17
3	12
4	161

Panel C: Second Deferred

CTI	Average Number of Brokers
1	63
2	8
3	6
4	63

Table 6.a. Interdealer Trading Options

Panel A: Nearby Contract

Trader	Opposite Trader	Percentage of Trades by Customer Type
Personal	Personal	22.82%
Personal	House	3.30%
Personal	Other Floor	3.97%
Personal	Customer	64.79%
House	House	0.05%
House	Other Floor	0.17%
House	Customer	1.29%
Other Floor	Other Floor	0.03%
Other Floor	Customer	0.62%
Customer	Customer	2.97%

Panel B: First Deferred Contract

Trader	Opposite Trader	Percentage of Trades by Customer Type
Personal	Personal	17.82%
Personal	House	3.42%
Personal	Other Floor	2.28%
Personal	Customer	71.30%
House	House	0.07%
House	Other Floor	0.09%
House	Customer	1.41%
Other Floor	Other Floor	0.02%
Other Floor	Customer	0.53%
Customer	Customer	3.05%

Panel C: Second Deferred Contract

Trader	Opposite Trader	Percentage of Trades by Customer Type
Personal	Personal	16.33%
Personal	House	2.99%
Personal	Other Floor	2.00%
Personal	Customer	72.82%
House	House	0.07%
House	Other Floor	0.10%
House	Customer	1.58%
Other Floor	Other Floor	0.02%
Other Floor	Customer	0.60%
Customer	Customer	3.50%

Table 6.b. Interdealer Trading Futures

Panel A: Nearby Contract

Trader	Opposite Trader	Percentage of Trades by Customer Type
Personal	Personal	11.95%
Personal	House	6.59%
Personal	Other Floor	1.36%
Personal	Customer	28.97%
House	House	2.58%
House	Other Floor	0.12%
House	Customer	16.27%
Other Floor	Other Floor	0.01%
Other Floor	Customer	0.54%
Customer	Customer	26.78%

Panel B: First Deferred Contract

Trader	Opposite Trader	Percentage of Trades by Customer Type
Personal	Personal	15.39%
Personal	House	9.34%
Personal	Other Floor	1.84%
Personal	Customer	44.58%
House	House	1.79%
House	Other Floor	0.12%
House	Customer	14.23%
Other Floor	Other Floor	0.01%
Other Floor	Customer	0.48%
Customer	Customer	27.60%

Panel C: Second Deferred Contract

Trader	Opposite Trader	Percentage of Trades by Customer Type
Personal	Personal	12.72%
Personal	House	8.53%
Personal	Other Floor	1.95%
Personal	Customer	39.90%
House	House	1.16%
House	Other Floor	0.12%
House	Customer	10.86%
Other Floor	Other Floor	0.01%
Other Floor	Customer	0.49%
Customer	Customer	24.26%

Table 7 End of Day Risk Parameter Positions Levels

Risk Parameter	Mean	Median
Position Delta	0.23	0
Position Gamma	0.65	0
Position Vega	-6.34	0

Table 8 Midday Risk Parameter Positions Levels

Risk Parameter	Mean	Median
Position Delta	2.17	0
Position Gamma	-3.23	0
Position Vega	-4.43	0

Table 9 Intraday Risk Parameter Position Levels Over Five Time Increments

Time Increment	Position Delta	Position Delta without Futures	Position Gamma	Position Vega
1	0.84	1.53	2.99	-1.47
2	2.02	1.73	-2.39	-4.24
3	3.71	3.57	-0.76	-2.62
4	4.63	4.78	-0.61	-3.49
5	5.37	5.76	-0.73	-4.23