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AN ANALYSIS OF TRADING IN OPTIONS ON EURODOLLAR FUTURES: TRADE TYPES, RISKS, AND PROFITS

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AN ANALYSIS OF TRADING IN OPTIONS ON EURODOLLAR FUTURES: TRADE TYPES, RISKS, AND PROFITS

A Dissertation APPROVED FOR THE PRICE COLLEGE OF BUSINESS

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1. Introduction

The aims of this study are multiple: to document actual trades executed by brokers in an option market; to present evidence of specialization among brokers; to assess profit distributions of option trades; to present information on the sensitivity of actual option positions to changes in the price of the underlying asset, volatility and time to expiration; and, to develop and test a new decomposition for option profits. Using a unique dataset that identifies clearing firms and trade types, I am able to make comparisons between the different clearing firms and assessments of actual trades in the market for options on Eurodollar futures[1]. The identifying mark for each trader and trade type is a major improvement in the field. The results are the first of their kind in the literature.

The literature is silent on the types of trades actually executed in option markets. Specifically, until now no researcher has documented the prevalence of spread and combination trades in an option market, which I show represent more than 50% of large trades. Previous research overlooks important information through inability to distinguish combinations from outright puts and calls. More specifically, straddles and strangles, which are examples of trades used to exploit actual and implied volatility, make up better than 20% of trades in the sample and vertical spreads comprise over 8% of all trades.

I document large differences among brokerage houses in the trade types they execute and investigate whether statistically significant differences exist. Using 23 active firms I provide the first empirical evidence that differences in trading preferences exist

[1] Throughout this study, "trade type" and "type of trade" will be used to indicate whether the trade is a call, a put or some combination of calls and puts such as straddles, bear spreads, strangles and horizontal spreads. Appendix I lists the combinations recognized by the Chicago Mercantile Exchange (CME).

between market participants. I find three firms specialize in puts, two in straddles, two in strangles, and one in calls.

Option partial derivatives with respect to the futures price, volatility, and time to expiration are important in hedging a portfolio and assessing portfolio risk. Many books mention the "Greeks", but very few explore their true effects in detail. This study documents the signs and magnitudes of the Greeks for actual large option positions. The deltas of straddles are found to be small relative to calls and puts, but have gammas and vegas that make them good for trading volatility. Notably, most bear spreads have significantly positive gammas and vegas, and negative thetas, when textbooks say they should be near zero.

I calculate the profit distributions for various trade types. A few authors, most notably Merton, Scholes and Gladstein (1978, 1982), have looked at returns to simple option positions, but not spreads and combinations. No one has documented returns (or profits) on a wide range of option positions. This study uses actual option trades with a variety of maturities, as opposed to simulated six-month calls used previously. Profit distributions are mostly non-normal with zero means. The standard deviation increases with the length of the holding period. Bullish trades are significantly profitable and bearish trades have significant losses.

I develop a decomposition of option prices to investigate which factors most influence profits on actual, large options positions: price changes, time decay or volatility. I do so by taking the total derivative of the position's price with respect to time. I then regress the profit on the changes due to changes in the futures price, implied volatility and time decay. Using beta coefficients I determine which is most influential.

For directional trades, changes in the futures price are most influential. For volatility trades, actual volatility, gamma, is more important than implied volatility, vega.

The study progresses as follows. The next chapter describes the dataset used throughout this study and presents some summary information on the options and combinations included in the dataset. The third chapter discusses actual trading practices relative to textbook coverage of option positions. The fourth chapter covers specialization in financial markets and reveals that significant differences exist among clearing firms. The fifth chapter details the option risk measures. The sixth chapter deals with profit distributions of option positions. The penultimate chapter presents a discussion on sources of profits in option trading. The final chapter contains conclusions and plans for further action.

2. Data Description

The data used here are unlike the data used in any previous study. Specifically, my dataset encompasses most large trades executed in the options on Eurodollar futures and contains information on the clearing firm, the size of the trade, and all options involved in a single trade. Thus, I can differentiate between outright trades in calls and puts and spreads and combinations of calls and puts. The inclusion of markers for which options are traded together is a major innovation in options research. Studies using the Berkeley Option Database or even the Commodity Futures Trading Commission's (CFTC) Computerized Trade Reconstruction (CTR) are limited to looking only at calls and puts, but not combinations. The CTR database includes an indicator that an option purchase or sale is part of a combination, but it is difficult to reconstruct the combination or spread[2]. The Berkeley database has no such indicator. A more detailed description of the data follows.

2.1 Collection and Description

Bear Brokerage generously provided the data which includes most large trades executed in options-on-Eurodollar-futures on the International Monetary Market (IMM) at the CME. Appendix II describes Eurodollar options and futures. A large trade is defined as a trade that involves 100 or more contracts for outright puts or calls or 100 units of a trade type. For example, 100 straddles would consist of 100 calls and 100 puts, but in this dataset it would be reported as 100 straddles, the unit. Bear Brokerage collected the data on trading days from May 12, 1994, through May 18, 1995 and their set includes 6,920 observations from 192 out of 258 total possible trading days. Information for the other 66 days during the sample period was not provided[3]. The dataset includes 9.6 million option contracts, which represent 47.17% of the trading volume in the options on Eurodollar futures market for all days in the sample, except expiration days[4].

For a comparison to other databases, let us look at how each would report an order for 500 straddles. Assume the executing broker divides the trade as follows: four market makers receive orders for 100 straddles, one broker receives 100 calls, and another broker 100 puts. In my dataset, the trade would be recorded as 500 straddles, which is the original order. The Berkeley database would record the order as two separate trades: 500 calls and 500 puts. The CTR files would record the trade as four trades of 100 calls and

[2] A small sample from the CTR dataset shows that the component parts of one combination are listed as clearing two hours apart. Even if one tried to use this data, it would be very difficult assess combinations and spreads.

[3] Reasons for missing days are misfiling, illness and vacations by the person in charge of data collection.

four trades of 100 puts between a broker and market makers, which may be marked as a spread, one trade of 100 calls between two brokers and one trade of 100 puts between two brokers, for a total of six trades[5]. Clearly, the different recording techniques leave much to be desired.

Each observation in my dataset includes:

- the date of the trade;
- a buy/sell indicator;
- an identification number for the clearing member initiating the trade (there is a separate number for market maker initiated trades);
- an identification number for the type of trade, outright calls and puts or combinations thereof. Appendix I lists the option combinations recognized by the CME;
- the net price of the trade. For spreads this is the difference in prices between the options bought and the options sold. For non-spread combinations, the trade price is the sum of the prices. The data set usually does not contain the prices of the individual options traded in a spread;
- the expiration month, exercise price, and a put/call indicator for each option included in the trade;
- the number of contracts traded of each option; and,
- the expiration month, number of contracts and price of futures contracts, if any, traded against the options.

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[4] Expiration days are excluded because the options that expire on those days are included in the volume figures.

[5] The CTR would actually have 12 entries, one for the buy side and one for the sell side of each individual transaction.

As the data was compiled, several screens were applied. The first and largest screen removed 413 market maker initiated trades[6]. Since the purpose is to look at the activities of the clearing members and trades initiated off the exchange floor, market maker trades are not of interest. The second screen eliminated 42 trades that contained more than five different options. A final set of screens removed 123 pricing errors and incomplete observations. For instance, an observation was not entered if all information was not recorded. Spread trades in which it was not clear which option was bought and which was sold were deleted. If the price recorded was not in the daily range for the specific option, that trade was not included in the sample. Further, if options were executed against futures of a differing expiration, these trades were removed. Calls (puts) traded against futures in a one-to-one ratio were converted to puts (calls) through put call parity and then included in the sample as puts (calls), since these trades create synthetic positions. The majority of these positions were deep in-the-money and resulted in a sale at a net cost of zero. This final screen converted seven calls into puts and four puts into calls.[7]

Option partial derivatives and prices are used to develop and test several hypotheses[8]. To calculate the partials and prices, I use Black's (1976) option on futures formula. This model is chosen because it is frequently used as the standard that more complex models are measured against (Rebonato (1996) and Hull (1997)). Also, Black's model is tractable and provides closed form solutions for the price and partial derivatives. Black's model requires five inputs: the underlying asset price, the riskless interest rate,

[6] A market maker in this study is a person whose primary income is derived from making markets in options on Eurodollar futures.

[7] The simple put-call parity formula was used to compute the price. For example, to convert a call into a put, I used Put = (Strike - Future) + Call.

[8] Recall that for combinations trades only the net price is recorded.

the volatility, the time to expiration, and the strike price. The date and trade information determine the exercise price and the time to expiration. If an option is traded with a futures contract, I use the actual futures price in calculations. If the option was not traded with futures, I use the arithmetic average of the opening, high, low, and settlement prices for the underlying futures contract on the trade date. The average price is used since the exact time of the trade is not recorded, so a time matched futures price is unavailable. The US Treasury bill or note with a maturity closest to that of the option is used as the risk free interest rate[9] and is collected from the Wall Street Journal. The implied volatility was obtained from the same source as the trades, Bear Brokerage. Approximately one hour before the close of trading, brokers ask the market makers for their estimate of the implied volatility for an at-the-money straddle. The brokers record the estimate on the sheet with the trade information. The use of the estimate for implied volatility the futures price introduces some errors in the price estimates and partial derivatives, but these errors tend to be small[10].

This section has described the unique dataset used in this study. The inclusion of specific information on the initiator of the trade and combinations and spreads makes for improved studies of option trading, as compared to other commonly used data sets which lack information on the initiator and only assess outright puts and calls. The next section provides some summary statistics regarding the data.

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[9] Then interest rate was changed to a Treasury bill when one with a matching maturity came into existence.
[10] The average difference between estimated and actual prices is less than one-half tick for outright puts and calls.

2.2 Summary Statistics

This section presents information on various characteristics of the sample data. Specifically, the average trade price and quantity of each trade type, the distribution of the exercise price over the expiration months, and the differences in strike prices and expirations for spreads and combinations are detailed.

Table I presents the mean price and volume for the different trade types in the sample. When the options were traded in conjunction with futures, I present the futures trade details. The table is divided into six panels, where each panel includes similar trade types. For example, Panel A includes trades in which only calls or puts, not both, are purchased. Panel C includes spreads and combinations in which the options have the same exercise month and generally different strike prices.

Calls tend to trade in larger quantities than puts, 900 contracts on average versus 790, but puts trade at higher prices on average, 15.64 ticks ($391) versus 12.63 ticks ($315.75). Overall, the average price is less than 20 ticks ($500) for most trades. The three most notable exceptions are straddles, strangles and doubles. Since these trades involve the purchase of two options, they would be expected to be relatively more expensive than other trade types.

The largest trades in terms of average size are put horizontal spreads (1523.1 contracts), call delta neutrals (1356.7), short collars (1352.2), long collars (1117.9), strangles (1059.5), and put doubles (1023.8). Over 7% of the entire sample were executed against futures, and almost 14% of combination trades were executed together with futures.

Table II presents the distribution of options traded by strike prices and expiration month in the sample. For options traded in spreads and combinations, each option in the combination is given an entry in the table[11]. Panel A contains the regular quarterly expiration and serial options. Panel B contains the MidCurve options[12]. As would be expected, longer maturities display a greater range in the strike prices traded. Serial options have maturities of three months or less and generally have a small range of traded strike prices, since Eurodollar futures tend to be less volatile near expiration. Options in the regular quarterly expiration months exhibit a wide range of strike prices traded because they have expirations up to 18 months. For an idea of how time to expiration and the range of strike prices relate, compare June and September 1994 options with June and September 1995 options. Both sets of expirations were traded at the beginning of the sample. The options expiring in June and September 1994 expire in about one month and four months, respectively, from the start of the sample. These expirations have a small range of strikes traded, with most activity concentrated in two or three strikes. The June and September 1995 expirations, which have 13 and 16 months to expiration, respectively, have a larger range of strike prices traded, with activity over many strikes.

Comparing Panel A to Panel B, the differences in length of trading show up in MidCurves as well. Like serial options, MidCurves have short maturities, six months or less, and exhibit a smaller range of strikes relative to regular quarterly expiration options[13]. Note that the actively traded strikes for MidCurve options are lower than actively traded strikes in Panel A. This occurs because the yield curve during the sample

[11] For example, a June 1995 94.25 straddle contains a June 1995 94.25 put and a June 1995 94.25 call. This would count two entries in the June 1995 94.25 strike in Table II.

[12] Appendix II describes the various option types.

[13] In 1997 the CME introduced one year MidCurve options with maturities up to one year.

period was upward sloping, implying the futures prices were declining. This downward slope appears in the next table when looking at diagonal option spreads.

Table III presents information on the differences in strike prices (Panel A) and expiration months (Panel B) for combinations and spreads in the sample. Panel A indicates that traders prefer to execute vertical (bull and bear) spreads at consecutive strikes approximately two-thirds of the time[14]. One possible reason is that the closer strike prices make the spread less expensive and it is easier for the spread to reach its maximum profit potential. Panel C of Table I lends some support to this, showing that the average net price of a vertical spread is traded between 11 and 13 ticks ($275 to $325). Very few vertical spreads are executed when the difference in strikes is greater than 50 basis points.

Compared to all other spreads and combinations, collars have the largest range of exercise prices, from zero to 400 basis points. Many investors use collars to hedge cash market positions with the intent to establish the collar at low, or no, cost. Table I supports this, showing that the average cost of a collar is only approximately five and one half ticks ($137.5).

As shown in columns 11 and 12 of Table III Panel A, many diagonal spreads (both puts (20) and calls (41)) are executed with a difference in strike prices of 1.00 or greater[15]. Looking at Panel B, there are many diagonal spreads in the zero category, which contains trades in which the expirations are five days or less apart, as MidCurve

[14] One vertical spread is executed with a difference in strike prices of 0.12. This difference in strike prices only comes into existence when the underlying futures contract has less than three months to maturity and were introduced near the end of the sample period. This has been suppressed in Table III. Table II shows these strikes, 9X.12, 9X.37, 9X.62 and 9X.87, are not traded frequently.

[15] Many of these diagonal spreads, especially calls, are between regular and MidCurve options. During the sample period, the yield curve had a steep positive slope (implying a steep negative slope in futures prices).

and normal options with the same expiration month do. For example, the September 1994 quarterly options expired on September 19, 1994 and the September 1994 MidCurve options expired on September 16, 1994, a difference of three days. On July 7, 1994 the September 1994 futures were at 94.75 and the September 1996 futures, the basis for the two year MidCurves, were at 92.75, a difference of 2.00. Combining the difference in expiration dates and futures price explains why so many diagonal spreads were executed in category zero and with strikes over 1.00 apart.

Also, as reported in Panel B of Table III, most horizontal spreads are executed with a difference in expiration of one or two months. This arises as traders spread serial options against regular quarterly options. Both options are based on the same underlying futures contract and traders are exploiting the difference in the time decay of the options.

This section has reported the average price and trade size for a variety of option trades. On average most trades cost less than 20 ticks ($500) and occur in quantities of approximately 850 units. Option series with a long time to expiration show a greater range of strike prices traded relative to those with short times to expiration. For spreads and combinations, most involve a difference in strike prices of 25 basis points and a difference in maturities of three months or less. A large proportion of diagonal spreads involves MidCurve and regular options on Eurodollar futures.

2.3 Summary

This chapter has described the dataset to be used throughout my dissertation. The main distinguishing facets of the data are the indicators for the initiating clearing firm and

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To create an approximately delta-neutral position between normal and MidCurve options, a spreader would have to find a large difference in strikes.

the type of trade executed. The firm indicator is used in Chapter 4 when I look at differences among clearing firms. The trade type indicator is used throughout the rest of the dissertation to assess the different combinations and spreads.

3. Actual Trading Practices

This chapter investigates option combination usage in an actual market. Since there is no extant research on this topic, the results presented here help fill in this gap and show the importance of combination trades in an option market.

While the variety of possible combination trades is unlimited, prior studies have been forced to assess only outright call and put trades because reliable information tracking combinations is lacking. This chapter shows that option combinations account for over 52% of large trades in the options on Eurodollar futures market. The relative importance of combination trades raises questions about the validity of prior research and lays a path for future research.

My data show that textbooks do a good job of discussing the most common trades, but should add several other combinations. To more fully develop these points, the remainder of this chapter is as follows. The next section provides information on combinations and spreads. A discussion of how the data will be used follows. The results are presented next. The final section is a brief summary.

3.1 Review of Relevant Literature

The research literature on option trading has generally focused on the accuracy of pricing models, informational efficiency, and analysis of call and put trades. No research pertains to combinations and spreads of calls and puts. Without knowing which combinations and spreads are actually used, academics have no guide into explaining why certain trades are popular and what to teach students.

While there has been no research into option combinations, textbooks do discuss combinations. Derivatives textbooks, such as Chance (1998), Cox and Rubinstein (1985), Hull (1997), and Kolb (1995), typically begin with discussions of outright calls and then progress to puts. This is a logical progression since outright calls and puts are the simplest and most common option trades. Following a discussion of outright positions, authors usually move the discussions to various combinations of puts and calls. While the coverage of different combinations varies from book to book, all describe vertical (bull and bear) spreads, straddles, strangles, and butterflies. Table IV documents the amount of space devoted to combinations and spreads. Only one author, Natenberg (1994), discusses all the different combinations and spreads documented in this study. The typical textbook description of the four common spreads and combinations is presented below.

According to textbooks, vertical (bull and bear) spreads are used to speculate on the direction of an asset's price. They involve buying one option and selling an identical option with a different strike price. A bull spread profits when the asset's price increases, and involves buying an option and selling another at a higher strike price. Alternatively, a bear spread, in which an option is sold and one with a higher strike is purchased, profits from price declines. Vertical spreads are popular because of their low cost as the premium from the option sold is used to offset the expense of the option purchased. Of course this reduction in premium limits the profit potential of the position.

A straddle is a trade where a put and a call with the same exercise price and maturity are both purchased or sold. Textbooks recommend the purchase of a straddle when an investor believes there will be a large price movement in the underlying asset, but is uncertain of the direction; they recommend selling a straddle when the underlying asset's price at expiry is expected to be near the exercise price. A strangle is similar to a straddle except that the call and put have different exercise prices. The uses for strangles are the same as those for straddles, but at a lower cost since at least one of the options is not at-the-money.

The final combination commonly discussed is the butterfly. A purchased, or long, butterfly requires the purchase of a call (put), sale (purchase) of two calls (puts) with a higher strike price, and the purchase of another call (put) with yet a higher strike price, where the strike prices are usually equally spaced. Long butterflies profit when the underlying asset price is near the middle strike price at expiration. A short butterfly profits when the underlying asset's price is far from the middle strike price. Butterfly trades are also recommended when one strike price is believed to be mispriced relative to the others. For instance, a butterfly would be purchased if the middle strike price is believed to be overpriced relative to the higher and lower strike options. While these four are not the only combinations discussed in the respective textbooks, they are the only four that appear consistently.

Of those textbooks canvassed in Table IV, only Kolb's discusses the effect of changes in implied volatility on option combinations. When discussing a long straddle, Kolb mentions changes in implied volatility increase the straddle's value. No textbook explicitly discusses trading strategies to exploit changes in implied volatility. Books aimed at practitioners stress the importance of changing volatility more.

Books written for practitioners refer to straddles, strangles, ratio spreads, and butterflies as volatility trades[16]. This comes from using these combinations to speculate on the future level of implied volatility. To profit from an increase in implied volatility, practitioner books recommend purchasing straddles and strangles or selling butterflies. An at-the-money straddle is the most sensitive to changes in implied volatility and offers the largest profit potential. Strangles and butterflies are less sensitive to changing implied volatility and have lower costs. The sensitivity of butterflies to changes in implied volatility is subtler than for straddles and strangles. Butterflies are usually traded such that the middle strike is at-the-money. At-the-money options are more sensitive to changes in implied volatility; thus, an increase in implied volatility increases their value faster than the other two calls. The net effect is a lower price for the butterfly when implied volatility rises.

Thompkins (1994) explains that the academic and practitioner books have the same view on straddles. The academic books stress straddles for large price changes of uncertain direction. This view exploits a straddle's high gamma, which makes it sensitive to actual volatility, though the books do not explain this. Practitioner books are exploiting a straddle's high vega to exploit implied volatility. Though they differ on the type of volatility to exploit, both sets of authors agree straddles are good volatility plays[17].

This section has reviewed the discussions of option combinations and spreads from textbooks. There are four spreads discussed in all texts covered in Table IV:

[16] See Baird (1993), Natenberg (1994) and Thompkins (1994) for detailed discussions.
[17] See Thompkins (1994) chapter three, especially pages 66-70.

vertical spreads, straddles, strangles and the butterfly spread. Of those sampled only Natenberg (1994) describes all spreads and combinations.

3.2 Results

This section compares option combinations covered in derivatives textbooks to those actually traded. Table I indicates the number of times each trade type is executed during the sample period. Here we can assess the popularity of the different combinations and compare them to those covered by textbooks. Outright calls and puts would be expected to be the most popular trade types due to their relative simplicity. The table sheds light on which option combinations are actively traded in practice, a previously unexplored area.

The number of large trades for each trade type is reported in the second column of Table I. As expected, outright puts (1814 trades) and calls (1494) are the two most common trade types. Together they represent 47.85% of all trades. The most commonly traded combination is the straddle (1135 trades), followed by vertical (bull and bear) spreads (566), strangles (364), ratio spreads (326), delta neutrals (253), and collars (177)[18].

Three of the four most commonly traded combinations are among the four combinations discussed in all six books in Table IV: straddles, strangles and vertical spreads. The fourth is the ratio spread which involves selling one at-the-money call (put) and buying more than one out-of-the-money calls (puts). It profits from a large change in the underlying asset's price. The ratio spread can profit when implied volatility rises

[18] The results are similar for trades broken down by buys and sells. They have been omitted for brevity.

because the purchased calls are more sensitive, in aggregate, than the written call. The ratio is usually determined to create a delta neutral position.

The fifth most common combination is the delta neutral that is used as a synthetic straddle. The sixth most common combination is the collar. Collars are similar to the underlying futures and are used to profit from a directional move in the underlying. Butterflies, which are mentioned by all textbooks, are the tenth most common combination or spread out of twelve. One reason butterflies are not traded frequently is they are high commission trades. It appears that textbooks do a relatively good job of suggesting combinations and spreads to discuss that are among the most frequently traded in practice.

4. Specialization

This chapter assesses differences in trades executed by clearing firms[19] in the options on Eurodollar futures market. Anecdotal evidence suggests that brokerage firms have areas of expertise, but no empirical evidence supports this. Using a chi-squared test and a series of t tests, I find differences in the trading practices of clearing firms. Specifically, I find eight firms specializing in call, put, or combination trading. Looking at the specialists, I find that they generally do not earn abnormal profits.

This chapter proceeds as follows. A review of related literature is next. The empirical models and hypotheses are presented after the review. Results of the empirical tests and a discussion follow. The final section summarizes the chapter.

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[19] A clearing firm has a direct relationship with the exchange's clearing house. All participants must be backed by a clearing firm before trading. The clearing firm is responsible for margin accounts.

4.1 Literature Review

Consideration of specialization in the brokerage industry is absent in the academic literature. Since there is no academic research in the area, anecdotal evidence is presented to motivate the argument and to allow for some assessment of specialization.

Hayes and Hubbard (1990) detail information on Euromarkets. They note that US banks and brokerage houses are usually lead underwriters on US dollar denominated Eurobond offers, while large Japanese brokerage houses are the lead managers on most yen denominated offers. Similar results hold for other currencies. The banks not only lead Euromarket offerings of issuers in their home country, but for any issuer using the banks' home currency. Thus, it appears that investment banks specialize in Euromarket offers in their home currencies.

Anecdotal evidence also indicates that certain brokerage firms specialize in particular fields. For example, Morgan Stanley and Goldman Sachs are considered to be institutional brokers serving the needs of firms with large capital requirements, while Merrill Lynch and Dean Witter are more retail oriented and concentrate on individual investors. Salomon Brothers and Goldman Sachs are known for their expertise in fixed income securities trading. In futures markets, Cargill and Archer Daniels Midland are known for excellence in grain trading. Similarly Bankers Trust is known for complex derivatives and J. P. Morgan for currency products. Organized derivative exchanges are large enough for member firms to develop the skills necessary to specialize in certain areas. The wide variety of trading opportunities in options markets makes it an excellent area to seek specialization.

4.2 Methodology

This section develops hypotheses and empirical tests used to address specialization. I construct a simple model to explain one possible reason for specialization and motivate the hypotheses. Then the test statistics are described.

Figure 1 presents a world without specialization (my null hypothesis). Traders with different trading needs would be randomly distributed among the brokerage firms. No brokerage firm would look different from the other firms; the distribution of clients would be evenly spread among all firms.

Figure 2 presents a world with specialization. Put traders execute most of their trades through one broker. Spread traders and straddle traders migrate to one firm as well. The firm appears as a specialist because it executes a disproportionately high percentage of its trades in one trade type. This represents the alternative hypothesis: Some clearing firms specialize in executing certain trade types. Specialization may arise because the firm has developed some special skill in assessing the trade type or because the firm's clients have a large hedging need in the given trade type.

Two steps are taken to make the analysis more focused: reducing the number of clearing firms and combining similar trade types. There are 72 different clearing members in the dataset. I define an "active" clearing member as one that executes at least one hundred usable, recorded trades during the sample period. Any clearing member executing less than 100 trades is included in the "Other" category. After filtering, the sample has 23 active firms and 49 in the "Other" category. The Other category accounts for 21.13% of the trades in the sample; while the three most active firms initiate 22.10% of trades in the sample. To reduce the number of trade types, those with similar payoffs at expiration are combined: 1) guts and strangles; 2) butterflies, iron butterflies, and condors; 3) horizontal, vertical, and diagonal straddle spreads; and, 4) ratio spreads and Christmas trees. This reduces the number of trade types from 21 to 14.

To determine if clearing firms specialize in specific trades, I first use a chi-squared to test the hypothesis that clearing firms are homogeneous with respect to trading practices. If this hypothesis is rejected, I then use t tests to assess which individual firms specialize in which specific trade types.

The chi-squared test performed for testing homogeneity of the clearing firms is

$$\chi^2 = \sum_{f=1}^{24} \sum_{t=1}^{14} \frac{(A_{tf} - E_{tf})^2}{E_{tf}} \tag{4.1}$$

where

A_{tf} = the actual number of trades of type t executed by clearing firm f, and

E_{tf} = the expected number of trades of type t executed by clearing firm f.

$= \dfrac{\text{Total Number of trade type t in Sample}}{6920} * \text{Number of trades by firm f}$

$$= \left(\frac{\sum_{f=1}^{24} A_{tf}}{6920} \right) * \sum_{t=1}^{14} A_{tf}$$

The null hypothesis is all clearing firms are alike. Hence E_{tf} equals the expected number of trades of type t executed by firm f under the null hypothesis. The alternate hypothesis is there are differences among the clearing firms and some may specialize.

If the chi-squared test finds differences among clearing firms, the following t statistic for the clearing firm/trade type pairs is calculated.

$$t = \frac{P_{tf} - P_t}{\sqrt{\frac{P_t * (1 - P_t)}{A_{tf}}}} . \qquad (4.2)$$

where

P_{tf} = the proportion clearing firm f's trades which are trade type t,

$$= \frac{A_{tf}}{\sum_{f=1}^{14} At_f}$$

P_t = the proportion of all trades of type t to all trades

$$= \frac{\sum_{f=1}^{24} A_{tf}}{6920}, \text{ and}$$

A_{tf} = the number of trades of trade type t by clearing firm f.

The null hypothesis for all of the t tests is that firm f is no more, or less, likely to engage in type t trades than clearing firms in general. Since there are 336 individual t tests, some clearing firm/trade type pairs will be significant by chance. Consequently, these t tests are most appropriately viewed not as tests of significance but as a diagnostic tool to indicate which differences are most meaningful once the chi-squared test has indicated that specialization may exist.

If specialization is found, I investigate whether specialist firms earn abnormal profits. The following statistic tests for differences in profits:

$$t = \frac{\pi_{special} - \pi_{non}}{\sqrt{\frac{s^2_{special}}{n_{special}} + \frac{s^2_{non}}{n_{non}}}} . \qquad (4.3)$$

where

$\pi_{special}$ = Specialist profits;

π_{non} = Nonspecialist profits;

$s^2_{special}$ = Variance of specialist profits;

s^2_{non} = Variance of nonspecialist profits;

$n_{special}$ = Number of specialist trades; and,

n_{non} = Number of nonspecialist trades.

The null hypothesis states no firm earns abnormal profits. Profits are calculated over three holding periods: one week, one month and expiration. For purchases, I calculate profits by subtracting the trade price from the settlement price at the end of the holding period. For sales, I subtract the settlement price at the end of the holding period from the trade price. This permits assessing trading skills over various horizons. All tests assume unequal variances.

This section derived a simple model of specialization. Chi-squared test and t tests are proposed to investigate specialization by clearing firms. The next section presents the results of these tests.

4.3 Empirical Results

This section reports the details of the chi-squared and t tests regarding homogeneity and specialization among traders. Both series of tests reject the null hypothesis clearing firms do not specialize, providing the first empirical evidence of differences among clearing firms. Further testing reveals specialists do not earn abnormal profits.

For each clearing firm, Table V Panel A shows the percentage of clearing firm f's trades which are of each type, P_{tf}. The result of the chi-squared test is at the bottom of Panel A. The chi-squared test easily rejects the null hypothesis that clearing firms do not specialize at the 0.1% level of significance. The rejection provides the first empirical evidence of differences among brokerage houses with respect to trading practices[20].

Using t tests I now investigate which individual clearing firms specialize in which specific trade types. Eight of my 23 clearing firms do a significantly higher proportion of their trading in one trade type relative to the entire sample, where "significantly" means that the null hypothesis of no difference is rejected at the 1% level of significance or better. Firm 1 does a significantly higher proportion of its trading in generics (over 11% versus about 4% for the sample). Firms 9, 11, and 13 specialize in trading outright puts (over 40% for each versus the sample's 26%), while firm 5 specializes in calls (32.98% versus 21.59% overall). Puts and calls are used to hedge or speculate on the direction of change in the underlying asset which, for options on Eurodollar futures, is the three month LIBOR.

Firms 2 and 8 specialize in straddles (40.61% and 32.26%, respectively, versus 16.40% average). Firms 5 and 14 specializes in strangle trading (about 13.30% and 22.15% versus 5.26%). Since these are volatility trades, these firms may have some specialized knowledge with respect to the changes in implied volatility.

Due to a large number of trade types, I repeat the χ^2 and t tests examining only the most popular trade types: calls, puts, straddles, strangles, vertical spreads, delta neutrals, and ratio spreads, which encompass almost 87% of all trades. Table V Panel B presents the results. As in Panel A, the χ^2 test rejects the null of homogeneity at the 0.1% level.

As in Panel A firms 9, 11 and 13 appear as put specialists. Firms 2 and 8 specialize in straddles, and firm 14 specializes in strangles. Firm 5 remains a call

[20] The tests are also performed over buy trades and sell trades separately. In both cases, the results are similar. Similar tests were performed over volume, the results are quantitatively the same.

specialist, but is no longer a strangle specialist. Thus, there is little difference in the amount of specialization.

Table VI presents the average profits for specialists and nonspecialists in Table V Panel A. For puts (firms 9, 11 and 13) and straddles (firms 2 and 8), all specialists are aggregated. Put specialists have profits greater (losses less) than nonspecialists do, but the profits are not significant in any holding period. The same holds for the straddle and strangle specialists. Only the call and straddle specialists have significant difference in profits. In the one-week and one-month holding period, firm 5 makes an addition profit of 5.26 ticks ($131.50). In the one-week period, straddle specialists earn an extra $38.15. In general, specialists do not earn abnormal profits.

I believe the primary reason specialists do not earn abnormal profits is the efficiency of the market. The options on Eurodollar futures are the largest short-term interest rate option market in the world, and the many participants keep prices within arbitrage bounds. Anyone expecting to make excess profits would be hard pressed.

4.4 Summary

This chapter provides the first empirical evidence of differences and specialization among the clearing members. A chi-squared test finds differences in the trading practices of clearing firms. I used t tests to find which firms specialize in specific trades. I find three firms specialize in put trading, two in straddle trading, and one in call trading. Further tests reveal none of the specialists consistently make abnormal profits. These results imply modelers may have to reevaluate the assumption of homogeneity.

5. Option Risk Measures

This chapter studies the risk profiles of various option portfolios. Risk managers are interested in how a portfolio's value changes when the input variables change. To do this, risk managers evaluate the partial derivatives of option prices, or the "Greeks", with respect to the underlying asset's price, time to maturity, and implied volatility: delta, gamma, theta and vega. I discuss which Greeks are important in the various portfolios, which allows risk managers to see what pricing factors affect their portfolios.

To develop the risk profiles, this chapter proceeds as follows. The first section discusses each Greek for calls and puts and their relevance for risk management. I then discuss the Greeks for portfolios of calls and puts. The second section describes the empirical methods used to investigate the signs and size of the risk measures. Section 5.3 presents the results of the empirical tests. The final section summarizes the chapter.

5.1 Risk Profiles

This section assesses the risk measures of various option portfolios. Subsection 5.1.1 briefly discusses each of the Greeks for calls and puts and qualitatively depicts their impact on option prices. Subsection 5.1.2 shows how to compute the Greeks for portfolios of options. Following this, I discuss the risk profiles of various portfolios. Throughout this chapter, I use the notation below.

$F = Futures\ \mathrm{Pr}\,ice$

$X = Exercise\ \mathrm{Pr}\,ice$

$\sigma = Volatility$

$\tau = Time\ To\ Maturity$

$r = Riskfree\ Rate$

$$d_1 = \frac{\ln\left(\frac{F}{X}\right) + \frac{\sigma^2\tau}{2}}{\sigma\sqrt{\tau}}$$

$$d_2 = d_1 - \sigma\sqrt{\tau}$$

5.1.1 Calls and Puts

In this subsection I define commonly used partial derivatives of option prices. I show how they are computed and the effect each has on the option's price.

The most important risk measure is delta, $(\partial C/\partial S)$. It measures how much an option's price will change for a one-tick increase in the futures price. Risk managers need to know delta in order to set up the riskless hedge required by pricing models. Deltas for calls and puts, respectively, are calculated from the following formulae.

$$Delta_C = e^{-r\tau}N(d_1) > 0 \tag{5.1}$$

$$Delta_P = -e^{-r\tau}N(-d_1) < 0 \tag{5.2}$$

$N(\bullet)$ is the cumulative normal distribution. The delta of a call is always positive because increasing futures prices increase a call's value. A put's delta is always negative because increasing futures prices decrease a put's value. Deltas change with changing futures prices. The changes are associated with gamma.

Gamma, $(\partial^2 C/\partial S^2)$, measures how fast delta changes when the futures price changes. Risk managers use gamma to estimate how much delta will change and when to rebalance their hedge portfolio. Using Black (1976), gamma is the same for calls and puts with the same exercise price. The formula is

$$Gamma_C = Gamma_P = \frac{e^{-r\tau}}{F\sigma\sqrt{\tau}} N'(d_1) > 0. \tag{5.3}$$

$N'(\bullet)$ is the normal density function. Gamma is always positive. Thus, any increase in the futures price will increase delta. Figure 3 plots the gamma of a call option. Note that it changes with respect to time to maturity and the futures price relative to the strike price. Gamma is largest when the futures price is at the strike price and decreases as the futures moves away from the strike. Gamma also increases for at-the-money options when the time to maturity decreases. Delta can make large, rapid swings when an option nears expiration.

As maturity approaches, the time value of an option decays. The measure of the decay is theta, $(\partial C/\partial \tau)$. This decay is small for long maturity options, but it is very large for short maturity options. Theta is computed from the following formulae.

$$Theta_C = -\frac{F\sigma e^{-r\tau}}{2\sqrt{\tau}} N'(d_1) + rFe^{-r\tau}N(d_1) - rXe^{-r\tau}N(d_2) \tag{5.4}$$

$$Theta_P = -\frac{F\sigma e^{-r\tau}}{2\sqrt{\tau}} N'(-d_1) - rFe^{-r\tau}N(-d_1) + rXe^{-r\tau}N(-d_2) \tag{5.5}$$

Theta can be positive, negative or zero under Black (1976). Figure 3 shows the theta of a call option. Like gamma, it is at an absolute maximum when the futures price is at the exercise price and for short maturities. When the future is less than the exercise price, theta becomes fairly constant. When the future is above the strike price, theta increases and eventually turns positive. When theta is positive, it is optimal to exercise the option early.

Delta, gamma, and theta are the only Greeks that appear in the in the partial differential equation for a derivative's price. Since the derivation assumes a constant volatility, vega, $(\partial C/\partial\sigma^2)$, is not a true Greek. In actual markets, volatility changes over time and this can dramatically affect an option's price. Risk managers need to know how this changing volatility will affect their portfolio. Like gamma, the vegas of calls and puts are the same.

$$Vega_C = Vega_P = Fe^{-r\tau}\sqrt{\tau}N'(d_1) > 0 \qquad (5.6)$$

Like gamma, vega is always positive and reaches a maximum when the futures price equals the exercise price. Unlike gamma, vega is largest for long maturity options and decreases as maturity approaches. Figure 3 shows the vega for a call option.

This subsection discussed delta, gamma, theta, and vega for call and put options. I also discussed the importance of each in risk management. These discussions are summarized in Panel A of Table VII. The next subsection discusses how to combine calls and puts into portfolios and how the Greeks are affected.

5.1.2 Option Portfolios

This subsection discusses the risk profiles of portfolios of options. The first part shows how to compute the Greeks for any position and straddles and bull spreads in specific. The last part discusses the risk profiles of many common option portfolios.

Option traders use different combinations to create positions that are more sensitive to one or more of the Greeks than to others. Since option combinations are linear combinations of the component options, their derivatives are linear combinations of the derivatives of the component options. By properly combining options in a spread or combination, a trader can amplify the Greek of choice while muting others. For instance, the delta of a portfolio (Δ_p) would be

$$\Delta_P = w_1\Delta_1 + w_2\Delta_2 + \ldots + w_n\Delta_n \tag{5.7}$$

where

$$w_i = \textit{Quantity of Option } i \ (\textit{Negative if Sold Short})$$
$$\Delta_i = \textit{Delta of Option } i$$

Likewise gamma, vega and theta of a portfolio are linear functions of the measure for the individual options. This linearity makes computing the Greeks very simple.

For example, an at-the-money straddle's delta is near zero because the call and put both have deltas near +0.5 and –0.5, respectively, that cancel each other when purchased. Since the other partial derivatives, theta, gamma, and vega, are of the same sign for calls and puts, the straddle is very sensitive to volatility and time decay. The large thetas and vegas show a straddle is very responsive to changes in time to expiration and implied volatility. The large gammas imply the straddle's delta will change rapidly with a move in the underlying asset[21]. More specifically,

$$DELTA_{Straddle} = DELTA_P + DELTA_C \approx 0 \tag{5.8a}$$

$$GAMMA_{Straddle} = GAMMA_P + GAMMA_C > 0 \tag{5.8b}$$

$$THETA_{Straddle} = THETA_P + THETA_C < 0 \tag{5.8c}$$

$$VEGA_{Straddle} = VEGA_P + VEGA_C > 0 \tag{5.8d}$$

On the other hand, a trader may want a position with gamma, theta, and vega near zero, but a positive delta. A bull spread accomplishes this. Since one buys a low strike call and sells a high strike call, the spread's delta is positive because delta decreases when the strike price increases. The other partial derivatives tend to offset each other when combined, since they have opposite signs.

$$DELTA_{Bull} = DELTA_{Low} - DELTA_{High} > 0 \tag{5.9a}$$

$$GAMMA_{Bull} = GAMMA_{Low} - GAMMA_{High} \approx 0 \tag{5.9b}$$

$$THETA_{Bull} = THETA_{Low} - THETA_{High} \approx 0 \tag{5.9c}$$

$$VEGA_{Bull} = VEGA_{Low} - VEGA_{High} \approx 0 \tag{5.9d}$$

Other combinations are created in a similar manner to those presented here. This flexibility makes options very useful tools for investors and speculators.

The signs of delta, gamma, vega, and theta are very protean; they change very quickly for many positions. To help describe these Table VII presents the signs for many option positions, under specific circumstances[22,23]. Figures 3 through 7 are presented to show how the Greeks change over a range of futures prices.

Panel A of Table VII contains calls, puts and doubles. Calls and puts are discussed in subsection 5.1.1. Doubles are a long position in two options with different strike prices. Their signs are the same as outright calls and puts, but are larger because there are two options.

Panel B contains straddles and strangles, where both a call and a put are purchased. The deltas tend to be near zero because the call and put's deltas cancel each other put (see equation (5.8)). Gamma, vega, and theta reinforce each other because they are the same sign for the component calls and puts. Delta neutrals are included here as well because they are synthetic straddles. Their signs are the same as those for straddles and strangles. Figure 4 displays gamma, vega and theta for a strangle. The gamma and

[21] Though not presented here, most straddles in the sample were at-the-money. For strangles, the vast majority had exercise prices surrounding the underlying futures price.
[22] Assumes the position is purchased.
[23] Table VII is adapted from Bookstaber (1991) and Natenberg (1994).

vega are both positive and theta is negative, like the call, but larger, because of the addition of the put.

Panel C presents option combinations and spreads involving two put or call options with the same expiration month, but usually different strike prices: vertical spreads and collars. These trades have definite deltas, but the signs of the other Greeks are small and indeterminate. Bull spreads and long collars have positive deltas, while bears spreads and short collars have negative deltas. Gamma, theta, and vega are approximately zero for these positions (See Equation 5.9)). Figure 5 shows gamma, vega and theta switching signs for vertical spreads. Long collars have large deltas because the sold put and purchased call have the same sign and complement each other when combined.

In Panel D of Table VII, the signs of ratio spreads and Christmas trees are presented. These are spreads in which more options are sold than purchased. It is assumed that the future is trading near the lower (higher) purchased strike price for call (put) trades. The delta is expected to be near zero because the ratio is usually set to make the position delta neutral. The signs for vega, theta and gamma assume that the sum of the sold options is greater than the purchased options. These trades are some of the most sensitive to the positioning of the futures relative to the strike prices. Gamma, vega, and theta change signs and magnitudes with changes in futures price, as graphed in Figure 6. Figure 6 is a put ratio spread where the higher strike is purchased once and the lower strike sold twice. The partial derivatives are at a maximum near the lower strike, and small between the strikes and above the higher strike price. Note that the Greeks switch signs when the underlying asset's price is above the higher strike price.

Panel E contains the approximate signs of the partial derivatives for option spreads of involving options with different expiration months, and possibly different exercise prices. It is assumed that the options are at-the-money and the nearest expiration option is sold. In this case, the Greeks partially offset each other. Gamma and theta are largest for the sold option, while vega is greatest for the purchased option. The net results are the gamma is negative and vega and theta are positive. The results may be misleading because most of calendar spreads in the sample involve options on different underlying futures (See Table III Panel B.).

The signs for butterfly trades in Panel F of Table VII assume the futures price is near the middle strike (between the middle strikes for condors) and these options are sold. The signs reflect the sold at-the-money options having larger vegas, gammas, and thetas than the purchased wing options. Since the number of options bought and sold are equal, the signs tend to cancel out. Figure 7 graphs gamma, vega, and theta for a purchased butterfly. At the "wing" strikes, the gamma and vega are positive and theta is negative. As the future moves towards the middle strike, the signs reverse. Over all futures prices, the Greeks are very small.

This subsection covered the Greeks of various option portfolios. Trades are designed to amplify certain Greeks and mute others. The signs of the Greeks for several positions were also discussed. The next section describes tests to investigate these signs.

5.2 Methodology

This section describes the empirical tools used to assess the Greeks of option portfolios. The most interesting tests are those for Greeks where the expected value is near zero. If they are significantly nonzero, we gain insight on how traders use these portfolios.

To test the Greeks, I compute several values. The first are the mean and standard deviation. These give an idea of the average value and how much dispersion in the values. They are used to compute the following t statistic.

$$t = \frac{\mu_j}{\sigma_j / \sqrt{n_j}} \tag{5.10}$$

where

μ_j = the mean value of delta for trade type j $= \frac{1}{n}\sum_{i=1}^{n} Delta_i$;

σ_j = the standard deviation of delta for trade type j $= \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(Delta_i - \mu_{Delta}\right)}$;

and,

n_j = the number of trades used in the estimate of Greek j.

The other value found is the median of the absolute values of the Greeks. This eliminates any canceling out and allows us to look at the magnitude of each Greek. Using the median, we can see what the middle size is without worrying about the sign. Taken with the results of the t tests, the median value lets us assess how close to zero the Greeks truly are.

Equations 5.1 to 5.7 are used to calculate the Greeks of each trade. Since the options are American, I test for early exercise[24]. If exercise is optimal, I set delta to ±1 and gamma, vega, and theta to zero. All trades are treated as described above. If the signs

[24] A call is exercised early if the estimated price Black (1976) price is less than intrinsic value, F-X. For a put, the test is the estimated price Black (1976) price is less than intrinsic value, X-F.

were reversed for sales, then the Greeks would tend to cancel each other out. The cancellation biases the Greeks towards zero.

The null hypothesis of the t tests is the Greek is zero. This is only true for those with expected value of zero, such as a straddle's delta and gamma, vega, and theta of vertical spreads. I use this null in order to gain insight on how traders use the different portfolios. To make a statement about a portfolio, we need gamma, vega, and theta to all be significant. The median absolute values permit assessment of a typical position that may be misleading by the mean. An example is a straddle's delta. It may take on any value between –1 and +1, though most are expected to be small. Opposing signs may make the mean zero, when it actually is not. The median absolute value eliminates this cancellation and lets us see how close to zero most deltas truly are.

This section described the tests to determine if the signs are significantly different from zero. I use the median absolute value to further explore the magnitudes of the signs. The next section presents the empirical results.

5.3 Results

This section presents the results of the t tests described in section 5.2. Table VIII contains the means and standard deviations of delta, gamma, vega and theta of many option positions. When a trade is executed against futures, the mean and standard deviation of the net delta are presented. Options traded with futures are usually done to achieve delta neutrality and the table is set up to show this. Table IX contains the median absolute values (MAV) of delta, gamma, vega and theta of many option positions. If a trade was executed with futures, the net position delta is used as the delta.

In Table VIII Panel A all Greeks are significantly nonzero, since delta, gamma, vega, and theta are definite calls and puts. Further tests show the average deltas of calls (0.3275) and puts (-0.3309) are significantly less than +/- 0.5, indicating they are out-of-the-money on average. Gamma and vega are both significantly positive and theta negative, as desired. The MAVs in Table IX are less than the means in Table VIII. The MAV deltas are less than 0.5 (0.3083 for calls and 0.3278 for puts). This provides further evidence that outright calls and puts are mainly out-of-the-money when traded. Results for double are similar.

Panel B presents the Greeks for straddles, strangles, and delta neutrals. The deltas of straddles (-0.0378) and strangles (-0.0366) are both small and significantly negative at the 0.1% level, though expectations were for zero deltas. The large standard deviations reveal that deltas take on large range of values. When traded against futures, the deltas are 0.0222 for straddles and 0.0443 for strangles. Both are indistinguishable from zero. The MAV delta for straddles and strangles are 0.0964 and 0.1035, respectively. We see most straddles and strangles are approximately delta neutral, but many are not.

It is not really surprising to find the negative deltas for straddles. Recall equations (5.1) and (5.2), the delta for a call and a put using Black (1976) are

$$\Delta_C = e^{-r\tau} N(d1) \tag{5.1}$$

$$\Delta_P = -e^{-r\tau} N(-d1) \tag{5.2}$$

where $d1 = \dfrac{\ln\left(\frac{F}{X}\right) + \frac{\sigma^2 \tau}{2}}{\sigma\sqrt{\tau}}$.

When the $F = X$, $d1 = \frac{\sigma\sqrt{\tau}}{2}$. Thus, $d1 > -d1$ and $N(d1) > N(-d1)$ and the delta of a call is greater than the delta of the put. An at-the-money straddle has a slightly positive delta. For options on Eurodollar futures, $F = 100 - \textit{Futures Price}$ and $X = 100 - \textit{Strike Price}$. This transforms Eurodollar calls into puts on the interest rate (floors) and Eurodollar puts into calls on the interest rate (caps). The at-the-money straddle, in this case, has a slightly negative delta.

Addressing gamma, vega, and theta, we see they are signed as expected. Comparing them to outright calls and puts, they are greater for straddles and strangles. Gamma and theta are less than those for the average call and average put combined, while vega is greater. Looking at the MAVs in Table IX, the differences are even greater, gammas and thetas smaller and vegas larger. To create a larger vega and smaller gamma and theta, straddles and strangles would use longer maturity options than outright calls and puts.

Panel C presents the Greeks of vertical spreads and collars. Since these trades are designed to be sensitive to directional price movements, the deltas must be nonzero and are. Gamma, vega, and theta are predicted to be zero, but for bear spreads and long collars they are not. Gamma (0.1243), vega (0.1761) and theta (-0.0620) for bear spreads are small, but significantly nonzero at the 0.1% level. With all significantly nonzero, we know the average bear spread is executed near the high (purchased) strike price. For long collars gamma (0.1458) is significantly different from zero.

Comparing the relative size of the Greeks, gamma, vega, and theta are much greater than delta for outright calls and puts. For vertical spreads, and bear spreads in particular, the Greeks are all approximately the same size. By selling an option, the

Greeks are muted as desired. Panel C in Table IX presents the MAVs for vertical spreads and collars. Like Table VIII the values of the Greeks for vertical spreads are again on a similar scale.

Mean deltas in Panel D are expected to be approximately zero, and they are. For put ratio spreads and Christmas trees, no Greek is significantly different from zero. As volatility trades, the signs of gamma and vega were expected to be nonzero. Call ratio spreads show the desired signs. The negative gamma (-0.5938) and vega (-0.5347) and positive theta (0.2180) show the sold options are more influential on the position's sensitivity to volatility, as hypothesized.

The MAVs of ratio spreads and Christmas trees in Table IX show most deltas are approximately zero, but many are not. It appears that delta neutrality is important in determining the ratio. The MAV vegas are less than outright calls and puts, but are much larger when compared to delta. These trades may still be volatility trades.

Butterfly trades in Panel F all have the desired signs, but only a few are significantly different from zero. The vega of butterflies (-0.2066) and iron butterflies (-0.2939) are both significant, as is the butterflies' theta (0.0798). Figure 7 shows this pattern occurs near the middle strike of the spread. Looking at the MAVs, we again see the Greeks are very small in all cases.

5.4 Summary

This chapter looked at risk profiles of option trades. I showed how to combine calls and puts to create portfolios with the desired risk characteristics. I then discussed the risk profiles of several portfolios. The results of t tests and median absolute values of the signs of option Greeks show several interesting results. Straddles and strangles have negative deltas, on average, but not very much so (about -0.035). Their MAVs reveal most are approximately delta neutral. Bear spreads have significant gammas, vegas, and thetas, when they were expected to be zero. Unlike other portfolios, the Greeks of vertical spreads are approximately the same size. Ratio spreads have MAV vegas comparatively larger than their MAV deltas, so they may truly be volatility spreads.

6. Distribution of Profits and Risks from Option Trading

This chapter covers profits and risks of option trading. Little research exists on risk and reward in option trading and their distributions. I document the profit distributions for several different trades over three holding periods. The results show the average return is zero in most cases and the profit distributions differ significantly from the normal. Bull spreads have significantly positive profits, while bear spreads have negative profits. When calls and puts are segregated by purchases and sales, I find bullish trades have significant profits.

The rest of this chapter is organized as follows. The first section discusses the relevant literature, and then the methodology is described. The penultimate section outlines my hypotheses and presents my results. The final section summarizes the work.

6.1 Review of Relevant Literature

The literature on risks, returns, and the distributions of profits in option positions is not very extensive. This section describes the research on the risk and return of option trades, beginning with Merton, Scholes, and Gladstein (1978, 1982). They provide a solid foundation, but only consider a few put and call positions. The other paper discussed is Slivka (1980), who considers puts and calls and a few combinations.

The most thorough analysis of risks and returns from option trading is Merton, Scholes, and Gladstein (1978, 1982), hereafter MSG. In their 1978 paper, MSG assessed the expected return and standard deviation of holding different combinations of call options, the underlying stock, and a riskless asset. They make no note of higher order moments. In their 1982 paper MSG compared the expected returns and standard deviations of similar positions using puts.

MSG (1978) simulated the prices of calls with six months to maturity at several strike prices: 90%, 100%, 110% and 120% of the stock's price. Over a series of 25 half year periods, they found calls written one-to-one against a stock, a covered call write, higher strike price calls had higher expected returns and correspondingly higher risk. All covered call positions had lower expected returns and risk than the stock held in isolation.

MSG also tested a portfolio of investments consisting of 10% invested in call options and 90% invested in a riskless asset. For these portfolios, the expected return and standard deviation increased with the strike price of the option. Options with strike prices equal to or 10% greater than the stock price produced superior returns at lower risk than an outright position in the stock. A closer inspection shows that in most cases less than 50% of the options are exercised, so the results for this test appear to be driven by a few stocks making large gains.

In MSG (1982) they performed simulations on positions involving puts and the underlying stock with payoff patterns similar to the call trades in MSG (1978). Again options with six months to expiration were used. They checked daily to determine if early exercise was optimal. If so, the put was exercised and the income placed in the riskless asset until maturity.

MSG compared naked put writing to covered call positions. As before, the higher strike options resulted in greater expected return and standard deviation. MSG showed the naked put has higher return and less risk than the covered call, even though they have similar payoff patterns. This is attributable to the early exercise of in-the-money puts because, once exercised, they could no longer contribute to the volatility of returns.

The second strategy examined was the protective put, in which the stock and put are purchased simultaneously. This has a payoff at expiration similar to the call/riskless asset portfolio. In general, the lower strike prices had a greater return and risk, opposite to the call portfolio. This is because the high strike put was in-the-money and was likely to be exercised early. Once exercised, return volatility disappeared because the proceeds are placed in the riskless asset. Puts with strikes below the stock price were less likely to be exercised and the overall return becomes more volatile.

Together these are some of the earliest, and most thorough, papers on expected returns and risk in options. One drawback is they only allow for changes in price and time to expiration, not changes in volatilities. Another drawback is that they look at only simple positions, not spreads or combinations. Most importantly, these are simulated, not actual, trades.

Slivka (1980) bridged part of the gap by looking at the risk and returns of several outright option positions and combinations, such as outright calls and puts, straddles, and delta neutrals. Slivka looked at the expected returns and standard deviations of positions in six-month options using simulated prices. He found that riskier positions did not necessarily have higher expected returns. In fact no position earned more than the riskless asset! He states this must be true for all properly priced options[25]. If this is the case, all possible positions should earn the riskless return, which they do not. This makes it difficult to compare his work with others because other results show a much different profile of return and risk characteristics.

6.2 Methodology

This section outlines the empirical methods used to calculate the distribution of option profits. The first part describes how profits are calculated and why profits and not returns are used. The second part discusses the normality tests. To calculate the distribution of profits, I compute the mean variance, skewness and kurtosis, of profits for each trade type. I look at profits over several holding periods to determine if there are any differences attributable to longer holding periods. Calls, puts, and straddles are separated by purchases and sales to investigate any differences.

Determining the actual profitability of a given trade is a very difficult endeavor. Since we do not know when actual positions are closed, difficulties arise because of incomplete data and the possibility of offsetting (and establishing) positions with combinations. Without a complete data set, finding the correct closing of a position becomes nearly impossible. Early in the sample some trades listed may be closing positions established before the data was collected. Likewise, some of the sample offsetting positions may be executed after the sample period ends. With 66 days missing in the sample period, further omissions occur.

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[25] This is true if the position is continuously hedged.

The second problem arises because a trader can close out a combination as it was executed or piecemeal, "legged out." For example, a trader could buy a straddle and then sell the puts one day and the calls a week later. Or a trader could offset one position while simultaneously entering another. Here a trader would buy a call initially, then sell a call spread which, in effect, sells the purchased call and creates a new long position in a call at a higher strike. These problems make determining true profits difficult.

To mitigate these problems three overlapping holding periods are used to estimate profits. A one-week period simulates short-term trading strategies. This allows the assessment of profits that occur very quickly for large, quick swings in the Eurodollar futures or rapid changes in implied volatility. The second is one month, which represents an intermediate time frame for looking at profits created by slower changes in the futures prices or implied volatility. The final holding period assumes trades are held to maturity, regardless of the time period. Since there is large open interest in options on Eurodollar futures, many trades are held to maturity and this holding period encompasses these. This period accommodates hedges, since many are held to maturity.

To calculate the profits of each trade, I use the settlement price of the options and futures prices at the end of each holding period. For purchases, I use the settlement price less the purchase price. For sales I use the selling price less the settlement price. In calculating profits, I use the actual number of ticks gained or lost, not percentage returns, on a per contract basis. Returns are not used because some positions have unlimited liability. For example, you can purchase a call and sell two calls at a higher strike, a call ratio spread, for a net debit. If the futures rallies well beyond the higher strike price, the position will have a negative value at expiration. Thus, you pay upfront and at expiration.

Also, if you sell an option and it expires out-of-the-money, it would have an infinite rate of return. The profits are calculated for each of the three holding periods. If a trade expires before the holding period concludes, it is excluded.

This part describes tests used to determine if the profit distributions of option trades are normal. The first is the Jarque-Bera (1981), a goodness of fit test. The second is the Shapiro-Wilk (1965), an analysis of variance test.

The Jarque-Bera test is based on the sample size, n, the skewness and the kurtosis of the distribution. The test statistic is calculated as follows.

$$JB = n\left[\frac{(Skewness)^2}{6} + \frac{(Kurtosis - 3)^2}{24}\right] \tag{6.1}$$

JB is asymptotically distributed as a chi-squared with two degrees of freedom. The null hypothesis is profits are normally distributed. This is a simple test that only addresses the third and fourth moments. The next test is more encompassing.

The Shapiro-Wilk (1965) test is based on the observations ordered from smallest profit (greatest loss) to largest profit. It is the ratio of the best estimator of the variance to the usual corrected sum of squares estimator of variance. It is between zero and one, and small values lead to rejection of the null hypothesis of normality. Unfortunately, smallness varies from sample to sample (SAS (1996)). The W statistic is found using the following formula.

$$W = \left[\frac{\left(\sum_{i=1}^{h} a_{in}\left(\overline{\pi}_{n-i+1} - \overline{\pi}_i\right)\right)^2}{\sum_{i=1}^{n}\left(\pi_i - \overline{\pi}\right)^2}\right] \tag{6.2}$$

where

$$h = \begin{cases} \dfrac{n-1}{2} & \textit{if } n \textit{ is odd} \\ \dfrac{n}{2} & \textit{if } n \textit{ is even} \end{cases},$$

$\overline{\overline{\pi}}_i$ *is* i^{th} *ordered observation*, and

a_{in} *is a weight from Shapiro – Wilk* (1965).

The W statistic has a highly skewed distribution. Critical points are found using simulations. The Shapiro-Wilk statistic determines how much the ordered observations deviate from those expected if the distribution they are drawn from is normal. Thus, it is similar to correlation coefficient for QQ plots. Shapiro, Wilk, and Chen (1968) show the W statistic is superior to alternative tests of normality under a variety of null hypotheses.

The standard deviations of the various trade types should not be the same. For example, volatility trades should have a larger variance of profits than call and put trades. Vertical spreads should have smaller variances than calls and puts because they exhibit limited profits and limited losses. To test this, I use the following F statistic.

$$F_{n_x-1, n_y-1} = \frac{s_x}{s_y} \tag{6.3}$$

where

s_x = the larger standard deviation; and,

s_y = the smaller standard deviation.

The null hypotheses for these tests are equal variances. If the null is rejected, the profit distributions do not have the same variance. I present two competing null hypotheses in section 6.3.1.

This section described the calculation of overall profits and risks in options on Eurodollar futures trading. Using several holding periods to simulate different trading strategies, I calculate the profit distributions of various option positions. I provide a description of tests of the normality of distributions.

6.3 Hypotheses and Results

This section outlines my hypotheses and presents my results for the profit distributions of the different trade types. The first subsection outlines the ideas for the means and standard deviations. The second subsection presents the results of the distribution computations.

6.3.1 Hypotheses

This subsection discusses my expectations for the profit distributions of several trade types. For ease of exposition, the discussion follows the order of Table VIII. The mean of every distribution is expected to be zero, because excess profits should not exist. In general, I expect longer holding periods will have larger standard deviations than the short periods because the increased time allows for a greater evolution of the inputs. For more specific expectations, Tables I, VIII, and IX, with the prices and mean and median absolute values of the partial derivatives, are used as a guide to develop hypotheses. Calls and puts are used as the basis of comparison.

I expect the distributions of all straddle profits and all strangle profits to have larger standard deviations because they can profit on price increases and decreases. The relatively large means and MAVs for gammas and vegas make straddles and strangles more sensitive to changes in actual and implied volatility. This leads to my first alternative hypothesis:

H_0: Call and put trades have the same variance as straddle and strangles.

H_{A1}: Straddles and strangles have higher variances.

On the other hand, the low deltas and high prices could dampen the standard deviations because large price movements are required to create profits. This leads to the second alternative hypothesis:

H_{A2}: Straddles and strangles have lower variances.

The empirical tests should determine which alternative is correct.

With respect to the third moment, there is no reason to expect a positive or negative bias for aggregated profits. Kurtosis may be less for straddles and strangles because the higher prices will reduce extreme profit outcomes. Since delta neutrals are synthetic straddles, I expect similar results.

Bull and bear spreads should have very limited distributions due to the limited loss and limited profit potential for both buys and sells. The comparatively small Greeks, except delta, make them insensitive to all inputs except price changes. This insensitivity and the limited profit potential should make the standard deviation smallest of all distributions. The limited profit and loss potentials will reduce the occurrence of extreme outcomes, thus dampening kurtosis. As with the other distributions, there is no *a priori* reason for the existence of skewness.

The large number of call, put, and straddle trades permits analyzing the distributions of purchases and sales. For all trades, I expect the average return to be zero. Comparing purchases and sales of the same trade type, I expect the standard deviations in each holding period to be the same. Because options have asymmetric payoff structures, I expect the distributions to be non-normal.

For calls and puts, I expect the distributions of purchases to have positive skew because of the limited loss and unlimited profit potential. For sales, the distribution should have negative skew because of the limited profits and unlimited losses. For straddles, the distributions should have the same skew as the call and put distributions, but less severe because the much higher prices of straddles. When comparing the standard deviations of purchases and sales of the same trade type, I do not expect any significant differences.

This subsection presented expected results for popular trades in the options on Eurodollar futures. The mean of each distribution is expected to be zero. Standard deviations are expected to increase with holding period length. Purchases are expected to display positive skew and sales negative skew.

6.3.2 Results

This subsection discusses the profit distributions for calls, puts, straddles, strangles, delta neutrals and bull and bear spreads. Profits are calculated in ticks over three holding periods. Table X displays the descriptive statistics of the distributions. As expected, most means are zero. The only exceptions are vertical spreads. Bull spreads earn 1.42 ticks ($35.50) over one-month and 3.75 ticks ($93.75) if held to maturity. Bear spreads lose between 0.66 ($16.50) and 2.12 ($53.00) ticks over the holding periods. This may be sample specific because the futures prices rose over most of the period.

The standard deviations monotonically increase for all trade types as the length of the holding period increases. This is expected because the longer time frame allows for greater evolution of the pricing inputs. The results of the F tests comparing the standard deviations are in Table XI.

For all holding periods, calls and puts have significantly different variances though they look similar for one-week and one-month. The difference is particularly wide in the expiration holding period (29.9948 for calls and 19.5230 for puts). The variances of vertical spread profits are significantly smaller than call and put variances in all holding periods. This is not unexpected because the vertical spreads have limited profits and losses.

When comparing straddles and strangles to calls and puts, we get mixed results. In the one-week holding period, call profits have a significantly larger variance than straddles and strangles. This supports the second alternative hypothesis that the low average and MAV deltas and high prices of straddles and strangles reduce profit volatility in shorter periods.

In the one-month holding period, straddle profits have a larger variance than put profits, but not calls. When the positions are held to maturity, the variance of straddle profits is significantly larger than the variances of call and put profits. This conforms to the first alternative hypothesis that volatility trades should have a larger dispersion of profits because of the large gammas and vegas.

Strangle profits are also significantly more variable than put profits, when held to maturity. In the one-week holding period, call profits have a significantly larger variance the strangle profits. In all other cases, the variances are indistinguishable.

The lack of consistently higher variances is surprising, especially when compared to calls. This too may be due to the general rise in the market during the sample period. The results neither reject nor support either hypothesis about the influence of delta, gamma, vega, and prices on profits. Further tests over a longer sample period and different assets may be required to validate or reject my results.

Looking at the skewness rows, we see calls and bull spreads generally the largest, but mainly decrease with the length of the holding period. With means greater than zero, significantly so for bull spreads, there appears to be a bullish bias in the futures prices. Straddles and strangles are the only trades to have consistently negative skewness. Their high prices seem to be difficult to overcome, leading to losses.

Only two trade types display a consistent, large deviation in kurtosis: calls are leptokurtotic and straddles are mesokurtotic. The kurtosis of calls ranges from 6.9401 to 9.0624; there is a large amount of extreme profits in call trading. The kurtosis of straddle profits decreases as the length of the holding period increases, starting at 2.01812 falling to 1.0834. The plot of the distribution reveals there is a large mass of profits between –25 and +40.

The last two rows in each panel present the results of the normality tests. Most distributions are non-normal. The Jarque-Bera does not reject in four cases: call delta neutrals in the one-week and expiration periods; put delta neutrals in the one-month holding period; and, bear spreads held to expiration. The Shapiro-Wilk test does not reject the null of normality for all put delta neutrals, all bear spreads, and bull spreads in the one-week and one-month holding periods. In general the option profits are not normally distributed.

It appears the null for calls is rejected because the distribution has thick tails. Straddles are non-normal due to the mesokurtosis. The negative skew and varying level of kurtosis lead strangle profits to be non-normal.

Figure 8 displays a representative sample of distributions. The one-month profits of calls, puts, straddles, strangles and vertical spreads are plotted. We see the distributions for vertical spreads are much more compact than the others are. Call, put, straddle, and strangle profit distributions look similar, but as Tables XI and XII showed they definitely are not.

Figures 9 and 10 show the profit distributions of purchased calls and sold calls, respectively, for the various holding periods. Figures 11 and 12 do the same for puts, while Figures 13 and 14 are for straddles. The differences between these and Figure 8 are stark. The distributions in Figures 9 through 14 are clearly skewed and the means are shifted.

Table XII is set up like Table X, but contains the moments for the distributions for calls, puts, and straddles broken down by purchases and sales. The most obvious difference is the means are significantly nonzero. Call purchases and put sales earn significant profits on average. Their opposites, call sales and puts purchases, suffer significant losses. When all trades were considered to together, the mean profit is zero. This aggregation hid an important finding. Combined with the significant profits on bull spreads and significant losses on bear spreads, we see a positive bias in the movement of Eurodollar futures during the sample period. Straddles only show significant profits (losses) in the one-month holding period.

The standard deviation pairs for each holding period do not differ significantly for any purchased and sold pair. This is as hypothesized. The skewness is a different story.

As expected, the purchased call distributions have positive skew and the sales distribution has negative skew. Puts are do not meet expectations. In the one week and expiration holding periods, the skew is opposite of the expected sign. Put sales show a positive skew and purchases show a negative skew. With the asymmetric payoff structure, purchases were expected to have the positive skew. This deviation from expectations may be a function of the positive profits earned by put sales. The skew of the straddle distributions conforms to the expectations: purchases have a positive skew and sales have negative skew.

Like the combine distributions, calls have fat tails, but the kurtosis is more severe for purchases. Put kurtosis tends to decrease as the holding period length increases. Given the flatness of the combined straddle distribution, it is not surprising to find mesokurtosis in the segregated distributions. The Jarque-Bera and Shapiro-Wilk tests reject the null of normality. This was hypothesized and given the skewness and kurtosis, not surprising.

This section presented my expectation and results for the profit distributions for the various trade types. In general, longer holding periods display greater variation than shorter periods. Calls have noticeably larger standard deviations than puts. Profit distributions for calls, puts, straddles, strangles and call delta neutrals are significantly different from the normal. Put delta neutral and vertical spread profits have normal distributions in my sample. When separated into purchases and sales, calls and put have significant profits. Bullish trades earn positive profits and bearish trades incur losses. Calls and straddles have larger variances of profits than the other trade types.

6.4 Summary

This chapter outlines the risk and profits of actual option trades. The previous literature has only explored a small sample of the universe of possible option trades. This study expands the literature by assessing a much broader array of option trades. Option trades have mean profits of zero. The standard deviation of returns increases with the holding period and complexity of the trade. The distribution of call profits has thick tail, while volatility trades have thin tails. Vertical spreads are the only trades that have significantly nonzero profits, but are the only category to have a normal distribution. Calls and puts exhibit excess kurtosis, while straddles and strangles exhibit a lack of kurtosis. The next chapter takes the analysis of profits one step further. I develop a method of determining which variables most influence profits. It isolates the impact of changes in volatility, the underlying asset and time to expiration on total profits.

7. Sources of Profits in Option Trading

This chapter further investigates profits from option trading. Several authors group some trade types as either directional or volatility. I investigate if these factors are in fact the primary influence on profits for those trades. To do this, I develop a method relating profits to changes in the underlying variables: the asset price, implied volatility, and time to expiration, allowing a separate analysis of each. I test which factor has the most influence on profits for each trade type using "beta coefficients." Beta coefficients measure the relative influence of the independent variables on the dependent variable. The results show futures price changes are most influential for directional trades. For volatility trades, actual volatility is generally more important than implied volatility.

This chapter unfolds as follows. The first section discusses the literature related to option profits. The second section describes the return generating process and the tests to assess the effectiveness of the several variables. The penultimate section gives the results of my tests. The final section summarizes this chapter.

7.1 Literature Review

This section discusses articles related to option trading profits. These papers find most profits derive from mispricing between trade prices and model prices. Though interesting, the results are dependent on the model chosen. Galai (1983) develops a model for assessing a hedged option's return by decomposing it into four parts: the opportunity cost of the investment, the return on the stock, the deviation of the option's price from a theoretical model, and an error created by daily rehedging. He goes on to simulate profits from trade data. Galai finds mispricing is the major source of profits in option trading. Thus, the changes in the actual price and stock hedge are minor contributors to the portfolio return.

Broughton and Chance (1993) use Galai's (1983) model to assess returns from Value Line option recommendations. Following Galai, Broughton and Chance use transaction data to simulate positions in the option and stock. Similar to Galai, they find that most of the return is generated from deviations between the actual trade price and the theoretical price. Broughton and Chance also find the pricing deviation increases as the

Value Line ranking on the underlying stock decreases; thus, the profits are not just driven by increasing prices of highly rated stocks.

Galai's (1983) argument is based on the assumption that the Black and Scholes (1973) model is correctly specified and his inputs are valid. There are several well-known biases in the Black-Scholes model which could cause the discrepancies between the model and actual prices, non-constant variance chief among them[26]. The major limitation is that profits arise because the trade price is different from the model price. Thus, all results are dependent on the pricing model chosen. Another limitation of their approach is the daily rebalancing of the position. The trades used in my study are most likely hedges of over-the-counter positions or purely speculative, and are unlikely to be hedged daily. These limitations make it hard to assess which factors influence profits.

7.2 Methodology

This section presents my derivation the sources of profits in option trades. I develop a simple method for calculating option profits, applicable to any option position. In contrast to Galai, the results should not rely on the model chosen. This involves totally differentiating the pricing formula and using delta, gamma, vega and theta to determine which has the greatest impact on profits.

To derive the factors that influence option profits, I totally differentiate the option position's price with respect to time. I decompose an option's return into changes due to the various inputs. For example, take the following definition of a call price and time to maturity,

$$C = C(F,\sigma,r,\tau), \qquad \tau = T - t, \qquad (7.1a, b)$$

where C is the call price, F is the futures price, σ is the volatility, r is the interest rate, τ is the time to expiration, T is the expiration date, and t is the current date. Taking the Taylor series expansion with respect to current time, t:

$$\frac{dC}{dt}=\frac{\partial C}{\partial F}\frac{dF}{dt}+\frac{\partial C}{\partial \sigma}\frac{d\sigma}{dt}+\frac{\partial C}{\partial r}\frac{dr}{dt}+\frac{\partial C}{\partial \tau}\frac{d\tau}{dt}+\frac{1}{2}\frac{\partial^2 C}{\partial F^2}\frac{d^2F}{dt^2}, \quad \frac{d\tau}{dt}=-1. \qquad (7.2a, b)$$

Since it is commonly viewed that changes in the underlying asset's price are the most important factor, I include the second derivative with respect to the futures price. Substituting the name of the partial derivative of the call price for its arguments, we obtain:

$$\frac{dC}{dt}=DELTA_C\frac{dF}{dt}+VEGA_C\frac{d\sigma}{dt}+RHO_C\frac{dr}{dt}+THETA_C[-1]+\frac{1}{2}GAMMA_C\frac{d^2F}{dt^2}. \qquad (7.3)$$

where

$$\text{DELTA}_C \equiv \frac{\partial C}{\partial F}$$

$$VEGA_C \equiv \frac{\partial C}{\partial \sigma}$$

and likewise for RHO_C, THETA_C, and GAMMA_C.

Since RHO_C is small[27], we omit it and obtain:

$$\frac{dC}{dt}\approx DELTA_C\frac{dF}{dt}+VEGA_C\frac{d\sigma}{dt}-THETA_C+\frac{1}{2}GAMMA_C\frac{d^2F}{dt^2}. \qquad (7.4)$$

Taking discrete changes in time gives us:

$$\Delta C\approx DELTA_C*\Delta F+VEGA_C*\Delta\sigma-THETA_C*\Delta t+\frac{1}{2}GAMMA_C*(\Delta F)^2. \qquad (7.5)$$

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[26] Black (1975) discusses possible sources and solutions to several.

[27] Interest rates are excluded because they have little effect on Black (1976) option prices. For example, the value of a call with six months to maturity with a strike price and underlying price equal to 94.50 and volatility of 20% changes by .0015 (.3024 to .3009) if the interest rate changes from 5% to 6%. Since the

For a put, we follow the same pattern and obtain:

$$\Delta P \approx DELTA_P * \Delta F + VEGA_P * \Delta\sigma - THETA_P * \Delta t + \frac{1}{2} GAMMA_P * (\Delta F)^2 . \tag{7.6}$$

Since combinations and spreads are linear combinations of calls and puts, their partial derivatives are linear combinations of the component put and call's partial derivatives. Hence a combination's profits will be linear combinations as well. This linearity makes assessing the factors determining the profit in option positions much easier. For example, a straddle is a combination of one put and one call. Assuming the same volatility, σ, for both the put and the call, the profits of a straddle are:

$$\begin{aligned} \Delta Straddle = \Delta P + \Delta C \approx\ & DELTA_P * \Delta F + VEGA_P * \Delta\sigma - THETA_P * \Delta t \\ & + DELTA_C * \Delta F + VEGA_C * \Delta\sigma - THETA_C * \Delta t \\ & + \tfrac{1}{2} GAMMA_C * (\Delta F)^2 + \tfrac{1}{2} GAMMA_P * (\Delta F)^2 \end{aligned} \tag{7.7}$$

$$\begin{aligned} \Delta Straddle = \Delta P + \Delta C \approx\ & (DELTA_P + DELTA_C) * \Delta F + (VEGA_P + VEGA_C) * \Delta\sigma \\ & - (THETA_P + THETA_C) * \Delta t + \tfrac{1}{2}(GAMMA_C + GAMMA_P) * (\Delta F)^2 \end{aligned} \tag{7.8}$$

$$\begin{aligned} \Delta Straddle = \Delta P + \Delta C \approx\ & (DELTA_N) * \Delta F + (VEGA_N) * \Delta\sigma \\ & - (THETA_N) * \Delta t + \tfrac{1}{2}(GAMMA_N) * (\Delta F)^2 \end{aligned} \tag{7.9}$$

The subscript "N" represents the net value. The straddle's profits are nothing more than the sum of the profits from the put and call. All combinations can be broken down in a similar manner.

A slight adjustment is made if the trade is executed with futures. The gamma, vega, and theta of a futures contract is zero, so I must recompute delta. Delta is calculated as

$$DELTA_{Position} = \frac{(Call\ Volume)DELTA_C + (Put\ Volume)DELTA_P + (Futures\ Volume)}{\min(abs(Call\ Volume), abs(Put\ Volume))}$$

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interest changes only a few basis points on average, omitting the portion of return due to changing interest

The denominator takes the smallest option volume to place the delta on a per contract basis.

To estimate profits, I multiply the partial derivative by the change in the appropriate variable over the holding period of interest to create the four independent variables.

$$DELIGHT = Delta_N * (F_T - F_0) \tag{7.10}$$

$$GAMBLE = \tfrac{1}{2} GAMMA_N * (F_T - F_0)^2 \tag{7.11}$$

$$VENTURE = VEGA_N * (\sigma_T - \sigma_0) \tag{7.12}$$

$$THIEF = THETA_N * (\tau_T - \tau_0) \tag{7.13}$$

The subscript "0" represents the value at the time of the trade; "T" is the value at the end of the holding period. F is the futures price, σ is the implied volatility, and τ is the time to expiration. Delta, gamma, theta and vega are the partial derivatives calculated in Chapter 5 using Black (1976). To calculate profits, I use the difference between the settlement price at the end of the holding period and the trade price.

Once the values are calculated, I regress the following equation:

$$PROFIT_t = \alpha + b_D DELIGHT_t + b_G\ GAMBLE_t + b_V VENTURE_t + b_T THIEF_t + \varepsilon_t \tag{7.14}$$

All b_i's are expected to be unity, if equation (7.5) is correct and ε_t is independent of DELIGHT, GAMBLE, VENTURE, and THIEF. The coefficient on VENTURE is potentially biased. The volatility may be measured with error for two reasons. The first has to do with the time of day. The trades occur throughout the day, while volatility is measured once a day. If implied volatility changes throughout the day, I use an inaccurate measure. The second reason pertains to the volatility smile. If implied volatility is related to strike price, using the measure for at-the-money options is a biased

rates will have little effect.

estimate. During the sample period, at-the-money options generally had a lower implied volatility than other options. Thus, we underestimate the true volatility of a given option. Measurement error biases the coefficient on VENTURE towards zero. This bias will possibly understate the true influence of changing implied volatility on profits.

The derivation of the model assumes inputs make very small changes over a short period of time. Since I look at profits from one week and up, the approximation becomes less reliable. The error term should increase with the holding period. Thus, longer holding periods should show lower explanatory power than shorter holding periods.

When the options are held to expiration, only futures price changes and time decay influence profit. To address this, VENTURE is omitted from the regression, leaving:

$$PROFIT_t = \alpha + b_D DELIGHT_t + b_G\ GAMBLE_t + b_T THIEF_t + \varepsilon_t \tag{7.15}$$

Since our interest is in determining which variable has the most influence on profits, we need a measure of influence. With all b_i's expected to be unity, the size of the coefficient is not a good measure. One solution is to use "beta coefficients." Goldberger (1964) describes beta coefficients as a method to determine which variable is most influential. For example, the beta coefficient for DELIGHT is calculated as:

$$\beta_D = b_D * \sqrt{\left(\frac{s_{DD}}{s_{PP}}\right)} \tag{7.16}$$

where

β_D = the beta coefficient for DELIGHT;

b_D = the regression parameter estimate for DELIGHT;

s_{DD} = the sum of squared deviations of DELIGHT; and,

s_{PP} = the sum of squared deviations of PROFIT.

Beta coefficients provide a unit free measure of the relative importance of each independent variable. The relative size of each beta coefficient determines the relative influence of the DELIGHT, GAMBLE, VENTURE, and THIEF on PROFITS. Beta coefficients measure the effect of a standardized change in an independent variable on a standardized unit of PROFITS. Thus, they allow a relative ranking of the importance of the independent variables. In a simple regression, the beta coefficient is the correlation coefficient between the independent and dependent variables. Unfortunately, no similar explanation holds in the case of multiple regression.

This section has covered the empirical methods I employ in this chapter concerning profits in option trades. I develop a new decomposition of profits from option trading which I use in a regression framework. I then discussed "beta coefficients" which will be used to determine the relative influence of the pricing variables on profits. The next section contains my expectations for profit tests outlined in this section.

7.3 Hypotheses and Results

This section presents my expectations for the results of beta coefficients for influence on option profits. Since beta coefficients give a relative, not absolute, measure of influence, hypotheses involving the importance of DELIGHT, GAMBLE, VENTURE, and THIEF are necessarily relative. After discussing expectations, I present the results.

7.3.1 Hypotheses

Developing strict hypotheses for the relative importance DELIGHT, GAMBLE, VENTURE and THIEF is very difficult. As mentioned in Chapter 5, the signs and magnitudes of an option position's partial derivatives are very protean.

In general, I expect DELIGHT's beta coefficient to be the largest for directional trades, such as calls, puts, and vertical spreads. Since these trades are designed to profit from changes in the underlying asset's price movements should be the dominant factor.

I expect GAMBLE and VENTURE's beta coefficients to be large compared to THIEF and DELIGHT's for volatility trades: straddles, strangles, and delta neutrals. These trades are designed to profit from large moves in implied volatility and large swings in the underlying price in either direction, especially in the shorter holding periods. Because large changes in the underlying futures price also determine profits, DELIGHT's beta coefficient should be fairly large. THIEF's beta coefficient will increase for short dated trades when theta is large. More specific hypotheses are below, and are summarized in Table XIII.

I expect DELIGHT's beta coefficient to be largest in call and put trades, since calls and puts are used to profit from the direction of the underlying price. GAMBLE and VENTURE's beta coefficients are expected to be next largest, but of uncertain order. The large gammas and vegas make it difficult to determine which will be more important. THIEF will only exert influence for short maturities.

For vertical spreads, DELIGHT's beta coefficient will be largest. With gamma, vega and theta mostly near zero and on the same scale as delta, GAMBLE, VENTURE and THIEF should exhibit little influence on profits. The relatively large delta leaves

DELIGHT as the main contributor to profits. As a directional trade, this is not unexpected, since they are designed to exploit movements in the underlying price.

The more interesting results will be for volatility trades. Since these trades can profit from large swings in the underlying asset, gamma, or changes in implied volatility, vega, we can tell which is more important in determining profits. Since delta neutrals are surrogate straddles, I include them with the straddle hypotheses.

With average and MAV deltas near zero and small median absolute values, DELIGHT's beta coefficient should be relatively small for straddles and strangles. Since these are volatility trades, I expect GAMBLE and VENTURE's beta coefficients to be largest. These tests allow me to see what has more influence, actual or implied volatility. For shorter holding periods, VENTURE should be larger because there is little time for large price changes, but implied volatility can shift quickly. As the length of the holding period increase, GAMBLE will become more influential as squared price changes increase. THIEF's beta coefficient should increase as the holding period increases.

With mean and MAV net deltas near zero with a low standard deviation, I expect DELIGHT to have little influence on delta neutral profits. With larger vegas and smaller gammas than calls and puts, on average, I expect VENTURE to have more influence than GAMBLE. THIEF should increase in importance as maturity decreases.

This subsection discussed the relative importance of DELIGHT, GAMBLE, VENTURE, and THIEF on profits for directional and volatility trades. DELIGHT, price changes, is expected to be most influential for directional trades, such as calls, puts, and vertical spreads. For volatility trades, GAMBLE, actual volatility, and VENTURE, implied volatility, are expected to be most influential, but of uncertain order.

7.3.2 Empirical Results

This subsection presents the results for the three holding periods. In most cases, DELIGHT is the major influence. For shorter holding periods, GAMBLE and VENTURE show some influence. THIEF has little influence in most cases on profits in my sample. Table XIV Panel A contains the regression coefficient estimates and beta coefficients for directional trades. Panel B contains the estimates for volatility trades.

For a one-week holding period, DELIGHT's beta coefficient is 0.7641 for calls, about 3.5 times larger than GAMBLE and VENTURE's beta coefficients in Panel A. For puts, DELIGHT's beta coefficient is 0.9576, about 4.5 times larger than GAMBLE and VENTURE's. Increasing the holding period to one-month increases DELIGHT's beta coefficient for calls (0.8936) and puts (0.9773). GAMBLE becomes slightly more influential, as we would expect since squared price changes are expected to be larger for longer holding periods, while VENTURE loses importance. Thus, price changes (DELIGHT) are the most important factor for call and put profits. In all four cases, THIEF is minor, but increases as the holding period increases.

For the expiration holding period, DELIGHT (0.6072) and GAMBLE (0.6554) are approximately the same size for calls. THIEF is larger than in one week and one month, but still exerts approximately half the influence of DELIGHT and GAMBLE. Price changes have the most influence on call profits. For puts, DELIGHT (1.2286) is the most influential variable. GAMBLE (0.9602) is second, followed by THIEF (0.7292). As with calls, price changes are more important than time decay.

Another directional trade is the vertical spread. Since these trades have significant deltas and near zero values for the other Greeks, it is expected that DELIGHT will have the most influence. For bull and bear spreads in all holding periods, DELIGHT's beta coefficient is clearly the largest. GAMBLE is second largest in most cases, further strengthening the case that changing futures price are most important in directional trades. While these spreads should have near zero gammas, and the means are, many are not near zero.

The more interesting cases, the volatility trades, straddles and strangles, are presented Panel B of Table XIV. Since they are intended to exploit volatility, it will be interesting to see which is more influential, actual (GAMBLE) or implied (VENTURE). In the one week holding period, GAMBLE's beta coefficient is greater than one half for straddles (0.5882) and strangles (0.5401). VENTURE's beta coefficient is a little smaller for both straddles (0.5018) and strangles (0.4601). DELIGHT's one-week beta coefficient is smaller than GAMBLE and VENTURE's for strangles (0.3357), but not for straddles (0.5171). Recalling that the average delta was small, the large standard deviation means there are many that are not zero. In this short holding period, actual volatility is slightly more important than implied volatility. This may occur because the measurement error in VENTURE. As the results stand, academic textbooks implicitly touting straddles and strangles for their high gammas appear to have the upper hand over practitioner books explicitly touting implied volatility.

In the one-month holding period, GAMBLE's beta coefficient is again the largest, 0.6420 for straddles and 0.7044 for strangles. VENTURE's beta coefficients are 0.4655 for straddles and 0.3694 for strangles. DELIGHT's beta coefficients are approximately one half for strangles and one third for straddles. Again actual volatility is the major influence on the profits of pure volatility trades. Changing implied volatility has some influence, but it decreases over longer holding periods. Thus, actual volatility is more important in determining profits than implied volatility.

In the expiration holding period, GAMBLE, greater than one for both straddles and strangles, still has largest influence on profits for straddles and strangles. THIEF is a good deal greater than DELIGHT for both straddles and strangles. Again, actual volatility is the most important factor for profits in volatility trades, but time decay does play a role.

Delta neutrals, as synthetic straddles, should have results similar to those of straddles. In general they do, but not in the one-week holding period. For call and put delta neutrals, VENTURE (0.6679 and 0.6180, respectively) is the most influential variable, followed by GAMBLE. This contrasts with straddles and strangles where GAMBLE is larger than VENTURE. As synthetic straddles, one would have expected similar results. As the name implies, changing underlying prices have little effect on profits in the short term for delta neutrals.

In the one-month period, GAMBLE is most influential, like straddles and strangles. THIEF is the next most influential, followed closely by VENTURE. As before DELIGHT's beta coefficients are very small. When the positions are held to expiration, GAMBLE is most influential, then THIEF.

This section finds that changes in the futures price are the main contributor to profits for directional trades: calls, puts, and vertical spreads. For straddles, strangles, and delta neutrals, actual price volatility influences profits more than changes in implied volatility for, at least in longer holding periods.

7.4 Summary

In this chapter, I separated an option's profit into four components: profits due to changes in time to maturity (theta), changes in implied volatility (vega), changes in the underlying asset's price (delta), and changes in the rate of the underlying asset price changes (gamma). I then used beta coefficients to determine which is most influential on the profits of several different option positions.

For directional trades, calls, puts and vertical spreads, delta is the most important factor in determining profits. For volatility trades, straddles and strangles, actual volatility (measured by gamma) is most important, at least for longer holding periods. Although straddles and strangles are often presented as non-directional volatility plays, changes in the underlying price still exert a major impact on profits (although not as much as the directional trades). However, delta neutral trades truly are; changes in the underlying asset price have little impact on profits.

8. Conclusions

This dissertation has covered two general areas: actual trading practices in the Eurodollar futures options market and profits generated by these trades. The first part looked at actual trades executed and whether the firms that executed the trades specialize in a specific trade type. The second part addressed the distribution of option profits and created a new decomposition of these profits. Together, they answer several questions and open paths to future research.

The academic literature has been quiet on option trading practices because of the lack of information. My data set provides details on the initiator of a trade and all the options (and futures) executed in the trade. This allows me to look beyond simple calls and puts to combinations and spreads. I found that outright calls and puts account for less than half of the total trades in the sample. The most popular combinations (in descending order of importance) are: straddles, vertical (bull and bear) spreads, strangles, ratio spreads, delta neutrals, and collars. Straddles, strangles, ratio spreads, delta neutrals are trades used to exploit changes in volatility, either actual (measured by gamma) or implied (measured by vega). Market practitioners use options to trade volatility. Thus, options are not necessarily redundant assets.

Using the other unique characteristic of the data, the clearing firm indicator, I look at the trading styles of the various clearing firms. I find eight firms specialize in one trade type or another. Three firms specialize in put trading, two in straddle trading, one in call trading, and two in strangle trading. This is the first empirical evidence of trading firms possess differences in trading styles. Interestingly, none of the specialists were capable of consistently earning abnormal profits.

In a transitional chapter, I assess the signs and magnitudes of option risk measures: delta, gamma, vega, and theta. They are collectively known as the "Greeks". I find trades designed to exploit volatility, straddles and strangles, have mean deltas near zero, but the median absolute values (MAV) reveal many are not. Straddles and strangles have large gammas, vegas, and thetas, on average and in MAV. Vertical spreads are designed to have gamma, vega, and theta near zero. Bear spreads have significant values for these Greeks, but on average they are small. The relative size of gamma, vega, and theta versus delta is small compared to other trades.

With regards to option profits, I do two things. First, I document the first four moments of the distributions and find most are not normal. Second, I create a new decomposition of option profits based on pricing factors. Directional trades are influenced mostly by changes in the underlying asset. Volatility trades are generally most influenced by changes in actual volatility.

Put and call profit distributions are leptokurtotic, like stock returns. Call profits have significantly higher variance than put profits, which appear to be driven by a larger number of extreme outcomes. Straddle distributions are mesokurtotic. Bull and bear, vertical, spreads are the only trades to have significant profits, with bulls making money and bears losing money. These trades are also the only ones not to consistently deviate significantly from the normal. When comparing variances, the vertical spreads' variances are significantly smaller than the other trade types. The variances of call and straddle profits are significantly larger than puts and strangles. Straddles have a significantly higher variance of profits than calls in the one-month and expiration holding periods.

When dividing calls, puts, and straddles by purchases and sales, very interesting results arise. I find bullish trades, call purchases and put sales, have significantly positive profits and bearish trades have significant losses. Straddle purchases and sales only have abnormal profits in the one-month holding period. Purchased call distributions have positive skew and the sales distribution has negative skew. In the one-week and expiration holding periods, put sales show a positive skew and purchases show a negative skew. With the asymmetric payoff structure, purchases were expected to have the positive skew. The skew of the straddle distributions conforms to the expectations: purchases have a positive skew and sales have negative skew.

Like the combined distributions, calls have fat tails, but the kurtosis is more severe for purchases. Put kurtosis tends to decrease as the holding period length increases. Given the flatness of the combined straddle distribution, it is not surprising to find mesokurtosis in the segregated distributions.

The final chapter looks at the sources of option profits. To do this I created a new decomposition based on the pricing inputs: changes in the underlying asset, time to maturity and implied volatility. I use "beta coefficients" to determine which factor has the most influence on profits over three holding periods.

For directional trades like calls, puts and vertical spreads, the most important factor is changes in the underlying asset's price. Since these trades are designed to exploit the futures price, this result is not surprising. The more interesting case is volatility trades: straddles, strangles, and delta neutrals. For straddles and strangles, actual volatility (measured by gamma) is generally the most important influence on profits. Changes in implied volatility (measured by vega) are secondary, followed by changes in the underlying price. For delta neutrals, implied volatility is most important in the one-week holding period and actual volatility is second. In the longer holding periods, actual becomes more influential.

My dissertation presented the first information on the importance of combinations in option trading and the size of the positions' risk measures. I showed that several clearing firms specialize in executing various trades, but none consistently earn abnormal profits. I documented the distributions of various option positions and found they tend to deviate from normality. The last chapter developed a new method of assessing influence on option profits. Actual volatility was the major influence on volatility trades and price changes were the most important for directional trades.

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Appendix I

Description of Combination Trades

Delta Neutral:	Execute options and futures such that that position's delta is zero.
Vertical Spread:	Buy a call (put) and sell a call (put) differing only in strike price. These are more commonly called bull and bear spreads.
Horizontal Spread	Buy a call (put) and a sell call (put) differing only in expiration month. Also known as calendar spreads.
Diagonal Spread:	Buy a call (put) and sell a call (put) differing in strike price and expiration month. Also known as calendar spreads.
Straddle:	Buy identical call and put.
Strangle:	Buy a put and buy a call at higher strike price with the same expiration month.
Gut:	Buy a call and buy a put at higher exercise price with same expiration month.
Butterfly:	Buy a call (put), sell two calls (puts) at a higher strike price, buy a call (put) at a yet higher strike price.
Iron Butterfly:	Buy a straddle and sell a strangle.
Condor:	Buy a call (put), sell calls (puts) at two higher strike prices, and buy a call (put) at yet a higher strike price.
Vertical Straddle Spread:	Buy and sell straddles differing only in strike prices.
Horizontal Straddle Spread:	Buy and sell straddles differing only in expiration months.
Diagonal Straddle Spread:	Buy and sell straddles differing in strike prices and expiration months.
Christmas Tree:	Buy a call and sell calls at two higher strike prices. Buy a put and sell puts at two lower strike prices.
Double:	Buy calls (puts) differing only in exercise price.

Ratio Spread: Buy X calls (puts) and sell Y calls (puts) differing in strike price.

Risk Reversal: Sell a put and buy a call differing only in strike price. These are also referred to as collars and fences.

Generic: All other combinations.

The following are recognized by the CME, but are not represented in the sample.

Future vs. Option: Execute a future one to one against an option, e.g., a covered call.

Synthetic: Buy a put (call) and sell a call (put) with the same strike price and same expiration month. Three are traded, but are listed as collars.

Jelly Roll: Buy one synthetic and sell another synthetic differing only in expiration months.

Strip: Buy (sell) calls (puts) at same strike price, in a sequence of expiration months.

Appendix II
Description Eurodollar Futures and Options

The Eurodollar futures are the most actively traded short-term interest futures in the world. The Eurodollar time deposit futures contract reflects the London Interbank Offered Rate (LIBOR) for a three-month, $1 million offshore deposit. A total of 40 quarterly futures contracts, spanning ten years, plus the four nearest serial (non-quarterly) months are listed at all times. The price is $100 - LIBOR$. The minimum price change during the sample was one basis point (.0001) and equivalent to $25.

All Eurodollar options are for one futures contract. The minimum price change is the same as for the futures contract, until within three months of expiration. These short maturity options have minimum price changes of one-half of one basis point (.00005) equal to $12.50. The normal difference in strike prices is 25 basis points for maturities greater than three months. For maturities less than three months, the strike increments are 12.5 basis points.

Most traded options expire with the associated futures contract in the quarterly cycle. These options trade on the first six futures expirations. As of October 1999 regular quarterly expiration options trade with expirations of December 1999, March 2000, June 2000, September 2000, December 2000, and March 2001.

Serial options are options whose maturities are not on the quarterly cycle. These options are priced off the future with the nearest maturity following the expiration of the option. For example, October 1999 and November 1999 serial options are priced off December 1999 futures.

A third type of option, the MidCurve option, was introduced in late 1993. These options have maturities of less than one year, but are priced off futures that have maturities greater than one year. For example, a one year MidCurve option expiring in December 1999 is priced off the December 2000 future; and, a two year MidCurve option expiring in December 1999 is priced off the December 2001future. Serial options on one year MidCurves have recently been introduced. If a December 1999 one-year MidCurve call option is exercised, the buyer of the option receives a long position in a December 2000 future and the seller of the option receives a short position in the December 2000 future.

Table I
Summary Statistics on Options Positions

This table contains the number of each trade type, average price and size (in contracts). When futures are traded with the position, information is included.

Trade Type[a]	Number of Option Trades	Average Option Price	Average Trade Size	Number of Futures Trades	Average Futures Size
Panel A: This panel contains trades which involve the purchase of only calls or only puts, but not both.					
Call	1494	$315.75	898.5		
Put	1814	$390.92	789.2		
Call Double	39	$628.85	943.6	4	1281.5
Put Double	63	$1,115.68	1023.8	4	390.5
Panel B: Option combinations involving the purchase of one call and one put, either directly or synthetically.					
Straddle	1135	$1,690.62	632.7	138	206.7
Strangle	364	$747.22	1059.5	3	39.7
Call Δ Neutral	108	$419.44	1356.7	108	485.2
Put Δ Neutral	145	$557.24	925.3	145	363.2
Panel C: Option spreads using options with the same expiration date, generally with different strike prices.					
Bull Spreads	247	$309.36	958.6	15	186.7
Bear Spreads	319	$280.53	860.5	23	274.3
Short Collar	98	$130.99	1117.9	17	796.4
Long Collar	79	$139.87	1352.2	18	748.3
Panel D: Spreads buying and selling an unequal number of options with the same expiration.					
Call Ratio	187	$121.19	907.8	3	669.7
Put Ratio	139	$126.44	738.6	3	196.7
Call Tree	19	$123.69	988.2		
Put Tree	39	$82.05	949.4	1	60.0
Panel E: Option spreads with different expiration months.					
Call Horizontal	36	$140.97	716.7		
Put Horizontal	28	$145.09	1532.1		
Call Diagonal	61	$126.23	844.7		
Put Diagonal	64	$252.15	886.3		
Panel F: Butterfly type trades.					
Butterfly	85	$171.62	583.5		
Condor	6	$133.25	491.7		
Iron Fly	11	$618.25	690.9		
Panel G: Miscellaneous					
Generic	265	$862.03	927.5	19	661.9
Straddle Spread	75	$535	860.3	2	350.0

[a]Trade types are described in Appendix I

Table II
Distribution of Daily Observations by Strike Price and Expiration Month

This table documents the number of times a strike price/maturity pair is traded in the sample. For example the June, 1994 95.25 options are traded 129 times. For combinations and spreads, each individual option is counted. Bold indicates quarterly expiration months.

Panel A: Quarterly and Serial Options

Exercise	Expiration Month and Year																				
Price	9405	**9406**	9407	9408	**9409**	9410	9411	**9412**	9501	9502	**9503**	9504	9505	**9506**	9507	**9509**	**9512**	**9603**	**9606**	**9609**	Totals
90.00																		2			2
90.25																1					1
90.50																	1				1
90.75																1	1	1			3
91.00														1		6	4	3			14
91.25														2		7	3	2	2		16
91.50														3		10	21	1	3		38
91.75														6		19	8	20	23		76
92.00											3	5		56		42	55	32	15	1	209
92.25											8	7		37		35	33	17	17		154
92.50								1	11	1	23	20		102		112	48	35	12	1	366
92.75					2			20	25	4	96	34	8	131	1	67	31	21	19	1	460
93.00					9			23	31	30	142	36	14	215	3	155	113	10	5	6	792
93.25					1			29	35	62	218	21	13	156	8	197	62	9	10	14	835
93.50				2	1	4	3	143	42	71	375	19	14	202	25	245	79	7	7	5	1244
93.75			3		19	22	39	351	15	6	332	3	15	155	39	136	51	9	7	44	1246
93.87														7							7
94.00	1		6	5	52	109	117	710	3		171	1	2	29	17	80	49	20	4	2	1378
94.25			16	11	103	96	81	587			42			10	1	18	15	7	1	1	989
94.50		7	77	25	228	25	8	225			28			8	1	18	6	1		5	662
94.75	1	10	126	94	441	3	2	71			13					5				2	768
95.00	2	74	93	81	357	2		39						1	1	7			1		658
95.25		129	9	17	135			12			1			2		1					306
95.50		15		2	36			2			3			1			1				60
95.75		5			11			2			2										20
96.00		3			13			1			3										20
Totals	4	243	330	237	1408	261	250	2216	162	174	1460	146	66	1124	96	1162	581	197	126	82	10325

Table II continued
Distribution of Strike Prices and Expiration Months

Panel B: MidCurve Options

Exercise Price	One Year MidCurves: Expiration Month and Year 9412	9503	9506	Totals	Two Year MidCurves: Expiration Month and Year 9406	9409	9412	9503	9506	Totals
91.00		1		1				2		2
91.25	1			1		1	4			5
91.50	2			2			7			7
91.75	9	2		11		11	29	12	1	53
92.00	15			15	6	12	45	13		76
92.25	13	2		15	3	19	30	6		58
92.50	9	3		12	6	43	30	11		90
92.75	3	6		9	17	39	34			90
93.00	1	4		5	18	48	11	1		78
93.25			1	1	18	26	2			46
93.50		5		5	4	10	1	1		16
93.75		1		1		3				3
94.00		1		1		3				3
Totals	53	25	1	79	72	215	193	46	1	527

Table III

Difference in Strike Prices and Months for Combinations and Spreads

This table presents information on the differences in strike and exercise prices for various combinations and spreads contained in the sample.

Panel A: Difference in strike prices.

The numbers in this panel represent the difference in strike prices for each trade type. The differences in strikes are in basis points, 0.25 is a 25 basis point difference.

Strike Differential	Call Doubles	Put Doubles	Strangles	Bull Spreads	Bear Spreads	Long Collar	Short Collar	Call Ratios	Put Ratios	Call Diagonals	Put Diagonals
0.00						2	1				
0.25	37	58	130	172	195	42	25	157	80	14	16
0.50	3	5	116	58	99	29	26	29	45	3	20
0.75			31	10	17	13	6	1	4	2	6
1.00			33	6	6	10	11		9	1	2
1.25			19		1	1	2		1	4	4
1.50			16	1						8	2
1.75			6			1	1			26	7
2.00			5							2	2
2.25			4				1			1	4
2.50											1
3.00			2				2				
3.25			1				2				
3.50			1								
4.00							2				

Panel B: Differences in time to expiration.

Category 0 is for options that expire within five days. Category 1 is for options with expiration differentials of one month. Category 2 is for options with expiration differentials of two month. Likewise for Categories 3 and 4. Category 5 is for differentials greater than four months.

Expiration Differential	Call Horizontals	Put Horizontals	Call Diagonals	Put Diagonals
0	3		39*	14*
1	22	20	8	4
2	4	5	1	10
3	5	2	13	34
4				1
5	2			1

*Normal and MidCurve options expire within five days of each other.

Table IV
Page Count Devoted to Option Spreads and Combinations

This table presents the number of pages, P, or paragraphs, Π, dedicated to discussing each spread or combination in each book. Kolb (1995), Chance (1998), Hull (1997), and Cox & Rubinstein (1985) are representative of academic textbook. Natenberg (1994), Bookstaber (1991) and Thompkins (1994) are representative of practitioner books.

	Kolb	Chance	Hull	Cox & Rubinstein	Natenberg	Bookstaber	Thompkins
Vertical Spreads	5P	8P	3P	1Π	10P	2P	6.5P
Horizontal Spreads	3P	5P	1.5P	2Π	6P	3P	11.5P
Diagonal Spreads	0	0	1Π	1Π	1P	0	0
Ratio Spreads	2P	2P	0	0	4P	5P	15.5P
Straddles	2.5P	6P	1.5P	1Π	2P	2P	8P
Strangles	2.5P	0	1P	1Π	2P	1.5P	8.5P
Butterflies / Condors	10P	5P	1.5P	2Π	3P	3P	9P
Collars / Fences	6P	0	0	0	2P	0	0

Table V

Trading Activity of Clearing Firms

This table reports the trading activity of clearing firms in the sample. Each cell contains the proportion of clearing firm f's trades of type t to the firms total number of trades (x100). For example, puts account for 11.86% of firm 1's trades. * and ** represent a significant difference between the firm and all firms in the sample percentages at the 1% and 0.1% level, respectively.

Panel A: All Trades

Clearing Firm	Puts	Calls	Straddles	Vertical Spreads	Ratio Spreads	Strangles	Generics	Delta Neutrals	Collars	Diagonal Spreads	Doubles	Butterflies	Straddle Spreads	Horizontal Spreads	Trades
1	11.86 *	15.98	17.30	6.59	7.91	2.64	11.20 *	7.58	2.47	6.59	0.82	0.82	5.11	3.13	607
2	13.88	13.27	40.61 **	4.69	4.49	5.92	5.71	4.90	2.86	0.41	0.82	0.20	2.04	0.20	490
3	27.55	16.20	20.37	4.17	4.63	10.42	1.85	4.86	0.69	0.69	6.48	0.23	1.16	0.69	432
4	19.13	18.11	23.72	9.69	6.89	2.81	3.57	7.14	1.53	0.26	2.30	3.57	0.51	0.77	392
5	29.52	32.98 *	6.38	5.59	5.85	13.30 *	2.13	0.00	2.66	0.53	0.00	0.53	0.00	0.53	376
6	24.06	23.48	19.13	7.83	9.57	1.45	6.38	1.45	2.32	1.45	0.58	0.58	1.16	0.58	345
7	24.31	25.23	8.92	10.46	5.54	1.85	4.62	7.69	3.08	1.85	0.62	3.08	1.23	1.54	325
8	27.60	10.04	32.26 **	7.53	2.51	4.30	2.15	6.45	3.23	0.36	0.72	1.43	1.08	0.36	279
9	43.78 **	29.49	8.76	6.91	2.76	5.07	0.46	0.92	0.46	0.00	0.00	0.46	0.00	0.92	217
10	24.62	26.13	15.58	12.56	7.04	2.51	1.01	1.51	1.51	5.53	1.01	0.00	0.00	1.01	199
11	40.68 *	22.60	6.21	10.73	1.69	0.00	0.00	4.52	5.65	1.69	3.95	1.13	0.56	0.56	177
12	34.86	18.29	10.29	7.43	6.86	13.14	3.43	1.71	0.57	2.29	0.57	0.00	0.00	0.57	175
13	54.04 **	22.98	5.59	1.24	4.97	5.59	1.86	0.62	0.00	0.00	1.24	1.24	0.00	0.62	161
14	26.58	20.89	12.66	0.00	0.63	22.15 **	5.70	0.63	3.16	0.00	6.96	0.63	0.00	0.00	158
15	22.97	22.97	25.00	2.70	5.41	4.73	0.68	0.68	1.35	1.35	2.03	10.14	0.00	0.00	148
16	40.28	36.11	4.17	5.56	6.94	0.69	0.00	0.69	4.86	0.00	0.00	0.00	0.00	0.69	144
17	29.20	18.98	12.41	18.98	3.65	4.38	2.92	0.00	2.92	2.19	0.00	2.19	0.73	1.46	137
18	34.59	11.28	11.28	17.29	12.03	3.01	0.75	2.26	4.51	0.00	0.75	2.26	0.00	0.00	133
19	29.37	24.60	6.35	21.43	0.79	2.38	3.17	1.59	1.59	0.00	0.00	5.56	3.17	0.00	126
20	27.87	17.21	13.93	14.75	6.56	4.92	1.64	6.56	4.92	0.82	0.00	0.00	0.82	0.00	122
21	25.45	26.36	1.82	2.73	3.64	14.55	7.27	0.00	0.00	13.64	0.91	0.00	0.91	2.73	110
22	23.08	14.42	23.08	12.50	7.69	11.54	3.85	0.96	0.96	0.00	0.00	0.00	0.96	0.96	104
23	26.73	20.79	27.72	5.94	1.98	4.95	4.95	0.99	1.98	2.97	0.00	0.99	0.00	0.00	101
Other	27.09	25.58	12.24	9.71	5.54	3.21	3.15	3.49	3.56	1.57	1.50	1.92	0.48	0.96	1462
All Firms	26.21	21.59	16.40	8.18	5.55	5.26	3.83	3.66	2.56	1.81	1.47	1.47	1.08	0.92	6920

Chi Squared = 2645.4 299 Degrees of Freedom

Critical Value at 0.1% = 380.3

Table V (continued)

Panel B: Popular Trades

Clearing Firm	Puts	Calls	Straddles	Delta Neutrals	Vertical Spreads	Strangles	Ratio Spreads	Number of Trades
1	16.98	22.88	24.76	10.85	9.43	3.77	11.32	424
2	15.81	15.12	46.28 **	5.58	5.35	6.74	5.12	430
3	31.23	18.37	23.10	5.51	4.72	11.80	5.25	381
4	21.87	20.70	27.11	8.16	11.08	3.21	7.87	343
5	31.53	35.23 *	6.82	0.00	5.97	14.20	6.25	352
6	27.67	27.00	22.00	1.67	9.00	1.67	11.00	300
7	28.94	30.04	10.62	9.16	19.45	2.20	6.59	273
8	30.43	11.07	35.57 **	7.11	8.30	4.74	2.77	253
9	44.81 *	30.19	8.96	0.94	7.08	5.19	2.83	212
10	27.37	29.05	17.32	1.68	13.97	2.79	7.82	179
11	47.06 *	26.14	7.19	5.23	12.42	0.00	1.96	153
12	37.65	19.75	11.11	1.85	8.02	14.20	7.41	162
13	56.86 **	24.18	5.88	0.65	1.31	5.88	5.23	153
14	31.82	25.00	15.15	0.76	0.00	26.52 **	0.76	132
15	27.20	27.20	29.60	0.80	3.20	5.60	6.40	125
16	42.65	38.24	4.41	0.74	5.88	0.74	7.35	136
17	33.33	21.67	14.17	0.00	21.67	5.00	4.17	120
18	37.70	12.30	12.30	2.46	18.85	3.28	13.11	122
19	33.94	28.44	7.34	1.83	24.77	2.75	0.92	109
20	30.36	18.75	15.18	7.14	16.07	5.36	7.14	112
21	34.15	35.37	2.44	0.00	3.66	19.51	4.88	82
22	24.74	15.46	24.74	1.03	13.40	12.37	8.25	97
23	30.00	23.33	31.11	1.11	6.67	5.56	2.22	90
Other	31.18	29.45	14.09	4.02	11.18	3.70	6.38	1270
All Firms	**30.18**	**24.86**	**18.89**	**4.21**	**9.42**	**6.06**	**6.39**	**6010**

Chi Squared=816.5 138 Degrees of Freedom

Critical Value at 0.1% = 195.08

Table VI
Specialists' Profits

Average profits are reported for specialists and nonspecialists over several holding periods.
The t statistic is for the differences in means.
* and ** signifies statistical significance at the 5% and 1% level or better.

	Week		Month		Expiration	
Puts	Mean	Number	Mean	Number	Mean	Number
Specialists	$21.68	173	($0.73)	222	$13.78	254
Others	$1.14	1104	($13.44)	1196	($13.43)	1560
Difference	$20.53		$12.71		$27.21	
t Statistic	1.27		0.42		0.71	
Calls	Mean	Number	Mean	Number	Mean	Number
Specialists	$66.57	86	$153.23	93	$158.37	124
Others	$8.41	930	$21.77	987	$1.12	1370
Difference	$58.16 *		$131.46 *		$157.24	
t Statistic	2.10		2.51		1.52	
Straddles	Mean	Number	Mean	Number	Mean	Number
Specialists	$14.80	212	($35.35)	251	$28.63	289
Others	($23.35)	662	($9.60)	736	($16.11)	846
Difference	$38.15 *		($25.76)		$44.74	
t Statistic	2.57		(0.71)		0.47	
Strangles	Mean	Number	Mean	Number	Mean	Number
Specialists	(22.73)	66	35.21	71	(7.35)	85
Others	(8.63)	194	(72.85)	227	(67.88)	279
Difference	(14.09)		108.06		60.52	
t Statistic	(0.58)		1.91		0.71	

Table VII
Expected Signs For Long Option Positions

This table shows the expected signs of the partial derivatives of various long option positions. Short positions have the signs reversed.

Trade Type[a]	Delta	Gamma	Vega	Theta
Panel A: This panel contains trades which involve the purchase of only calls or only puts, but not both.				
Calls	+[b]	+[b]	+[b]	-[b]
Puts	-[b]	+[b]	+[b]	-[b]
Call Double	+[b]	+[b]	+[b]	-[b]
Put Double	-[b]	+[b]	+[b]	-[b]
Panel B: Option combinations involving the purchase of one call and one put, either directly or synthetically.				
Straddle	~0	+[b]	+[b]	-[b]
Strangle	~0	+[b]	+[b]	-[b]
Call Δ Neutral	~0	+[b]	+[b]	-[b]
Put Δ Neutral	~0	+[b]	+[b]	-[b]
Panel C: Option spreads using options with the same expiration date, generally with different strike prices.				
Bull Spreads	+[b]	~0	~0	~0
Bear Spreads	-[b]	~0	~0	~0
Long Collar	+[b]	~0	~0	~0
Short Collar	-[b]	~0	~0	~0
Panel D: Spreads buying and selling an unequal number of options with the same expiration.				
Call Ratio[c]	~0	-	-	+
Put Ratio[c]	~0	-	-	+
Call Tree[c]	~0	-	-	+
Put Tree[c]	~0	-	-	+
Panel E: Option spreads involving two different expiration months.				
Call Horizontal[d]	~0	-	+	+
Put Horizontal[d]	~0	-	+	+
Call Diagonal[d]	~0	-	+	+
Put Diagonal[d]	~0	-	+	+
Panel F: Butterfly type trades.				
Butterfly[e]	~0	-	-	+
Condor[e]	~0	-	-	+
Iron Fly[e]	~0	-	-	+

[a]Trade types are described in Appendix I

[b]Sign is valid under all circumstances.

[c]Sign assumes the at-the-money option is purchased.

[d]Sign assumes near maturity option is sold.

[e] Sign assumes middle strike price(s) sold.

Table VIII
Mean Partial Derivative Values

This table contains the means and standard deviations of the partial derivatives. When futures are traded with the position, the position delta is included. All positions are assumed long.
* and ** represent significance at the 1% and 0.1% level or better

Trade Type[a]	Number	Option Delta	Gamma x100	Vega	Theta	Futures Trades	Position Delta
Panel A: This panel contains trades which involve the purchase of only calls or only puts, but not both.							
Calls	1428	0.3275 **	0.9052 **	0.8606 **	-0.3906 **		
		0.2022	0.7574	0.5674	0.2942		
Puts	1752	-0.3309 **	0.7348 **	1.0372 **	-0.3694 **		
		0.1940	0.6033	0.6687	0.2607		
Call Double	39	0.4968 **	0.7457 **	2.1708 **	-0.4416 **	4	-0.0055
		0.4103	0.7108	1.2592	0.2612		
Put Double	63	-0.6877 **	0.9102 **	2.6630 **	-0.5133 **	4	-0.0136
		0.3617	0.4556	1.3481	0.1973		
Panel B: Option combinations involving the purchase of one call and one put, either directly or synthetically.							
Straddle	1113	-0.0378 **	1.4476 **	3.3089 **	-0.6753 **	136	0.0222
		0.2513	1.3664	1.7016	0.6869		0.1182
Strangle	355	-0.0366 **	1.2623 **	2.2550 **	-0.6503 **	3	0.0443
		0.1985	0.7417	1.1748	0.3954		0.2474
Call Δ Neutral	90		0.6395 **	1.3171 **	-0.3171 **	90	-0.0025
			0.5496	0.7073	0.2062		0.0410
Put Δ Neutral	122		0.5810 **	1.4025 **	-0.3000 **	122	0.0074
			0.4471	0.7544	0.1505		0.0320
Panel C: Option spreads using options with the same expiration month, generally with different strike prices.							
Bull Spreads	244	0.2271 **	-0.0394	-0.0168	0.0096	15	0.0136 **
		0.1306	0.5100	0.3661	0.1968		0.0107
Bear Spreads	313	-0.2161 **	0.1243 **	0.1761 **	-0.0620 **	23	0.0048
		0.1028	0.4451	0.3239	0.2203		0.0287
Short Collar	95	-0.6430 **	0.0058	-0.0028	-0.0041	17	-0.0273
		0.1578	0.2041	0.2033	0.0736		0.0767
Long Collar	77	0.5594 **	0.1458 **	0.0448	-0.0470	16	-0.0093
		0.2134	0.3366	0.2719	0.1041		0.0646
Panel D: Spreads buying and selling an unequal number of options with different strike prices.							
Call Ratio	180	-0.0158	-0.5938 **	-0.5347 **	0.2180 **	3	0.0383
		0.2223	1.2350	0.6429	0.3566		0.0334
Put Ratio	133	0.0021	-0.3981	-0.7947	0.2087	3	-0.1691
		0.2123	0.5350	0.9069	0.2655		0.2804
Call Tree	18	-0.0125	0.3445	0.1674	-0.2940		
		0.2151	1.1529	0.9752	0.8049		
Put Tree	37	-0.0256	-0.1257	-0.1895	0.0688		
		0.0926	0.4263	1.0526	0.2198		
Panel E: Option spreads involving two different expiration months.							
Call Horizontal	34	-0.0001	0.0382	-0.0159	0.0657 *		
		0.0401	0.1726	0.0527	0.1373		
Put Horizontal	23	-0.0074	0.0055	0.0113	0.0507		
		0.0457	0.1782	0.0869	0.1642		
Call Diagonal	59	0.1409	0.0990	-0.2207	-0.1253		
		0.5101	1.0122	0.6996	0.3415		
Put Diagonal	63	-0.0533	0.0015	-0.0755	-0.0405		
		0.4393	1.0478	0.5907	0.3387		
Panel F: Butterfly type trades.							
Butterfly	80	-0.0329	-0.1284	-0.2066 **	0.0798 **		
		0.2675	0.6036	0.2601	0.2003		
Condor	5	-0.0362	-0.1913	-0.1686	0.0912		
		0.0485	0.3965	0.3238	0.1907		
Iron Fly	11	-0.0060	-0.0885	-0.2939 *	0.0505		
		0.0144	0.1629	0.2927	0.6851		

[a]Trade types are described in Appendix I

Table IX
Median Absolute Value of the Partial Derivative

This table contains the median absolute values of the partial derivatives.

Trade Type[a]	Number	Position Delta	Gamma x100	Vega	Theta
Panel A: This panel contains trades which involve the purchase of only calls or only puts, but not both.					
Calls	1428	0.3083	0.6861	0.7561	0.3118
Puts	1752	0.3278	0.5762	0.9759	0.3008
Call Double	39	0.3753	0.4124	2.6634	0.4171
Put Double	63	0.7191	0.8585	2.9042	0.5577
Panel B: Option combinations involving the purchase of one call and one put, either directly or synthetically.					
Straddle	1113	0.0964	1.0097	3.1459	0.5805
Strangle	355	0.1035	1.0653	2.1491	0.5661
Call Δ Neutral	90	0.0087	0.5585	1.1692	0.2688
Put Δ Neutral	122	0.0124	0.4304	1.3656	0.2796
Panel C: Option spreads using options with the same expiration month, generally with different strike prices.					
Bull Spreads	244	0.1953	0.1953	0.2685	0.0882
Bear Spreads	313	0.1955	0.1585	0.2922	0.0864
Short Collar	95	0.6687	0.0471	0.1062	0.0210
Long Collar	77	0.5838	0.0797	0.1213	0.0431
Panel D: Spreads buying and selling an unequal number of options with different strike prices.					
Call Ratio	180	0.1182	0.4433	0.4044	0.2121
Put Ratio	133	0.1061	0.3689	0.6279	0.2224
Call Tree	18	0.1014	0.2828	0.7589	0.1964
Put Tree	37	0.0767	0.2505	0.7215	0.1931
Panel E: Option spreads involving two different expiration months.					
Call Horizontal	34	0.0097	0.0471	0.0084	0.0441
Put Horizontal	23	0.0071	0.0300	0.0106	0.0246
Call Diagonal	59	0.5211	0.9583	0.7753	0.3517
Put Diagonal	63	0.3249	0.5622	0.3898	0.2359
Panel F: Butterfly type trades.					
Butterfly	80	0.0559	0.1049	0.1677	0.0726
Condor	5	0.0220	0.0505	0.1187	0.0282
Iron Fly	11	0.0083	0.1622	0.2641	0.0613

[a]Trade types are described in Appendix I

Table X
Statistics for Profits Distributions

This table presents the mean, standard deviation, skewness and kurtosis of profit distributions for several trade types. The Jarque-Bera and Shapiro-Wilk statistics test if the distribution is normal. * and ** represent significance at the 1% and 0.1% level, respectively.

	Calls	Puts	Straddles	Strangles	Call Delta Neutrals	Put Delta Neutrals	Bull Spreads	Bear Spreads
Panel A: One Week Holding Period								
Mean	0.5335	0.1570	0.2220	-0.4885	-0.1319	0.4825	0.7181	-0.6595 **
St. Dev.	8.4645	6.3513	7.0694	6.2586	2.6681	4.3440	4.0220	2.8595
Skewness	0.7004	0.1461	-0.0297	-0.6116	0.8208	0.6548	1.2673	-0.2097
Kurtosis	8.9540	4.4194	2.0812	8.5236	2.7064	3.7701	2.5394	0.3485
n	1016	1277	874	260	71	101	180	228
Jarque-Bera	1583.79 **	111.74 **	30.87 **	346.74 **	8.23	9.71 *	49.77 **	68.46 **
Shapiro-Wilk	0.8574 **	0.9474 **	0.9722 **	0.8644 **	0.9462 **	0.9719	0.9140	0.9720
Panel B: One Month Holding Period								
Mean	1.3236	-0.4580	-0.6560	-1.8842	2.0889	0.5767	1.4219 *	-1.5508 **
St. Dev.	17.3471	14.6492	19.3672	14.9275	8.1801	7.6732	7.3499	6.3140
Skewness	1.1607	0.0117	-0.0901	-0.9548	1.5462	0.5306	0.0413	0.1925
Kurtosis	6.9401	2.3082	1.6061	3.4553	4.8442	2.3142	1.3108	0.3780
n	1080	1418	987	298	86	122	204	264
Jarque-Bera	941.09 **	28.31 **	81.25 **	47.85 **	46.45 **	8.12	24.31 **	77.25 **
Shapiro-Wilk	0.8643 **	0.9534 **	0.9658 **	0.9373 **	0.9069 **	0.9701	0.9834	0.9746
Panel C: Expiration Holding Period								
Mean	0.9378	-0.3842	-0.1886	-2.1497	-0.5905	1.9095	3.7512 **	-2.1163 *
St. Dev.	29.9948	19.5230	49.3686	32.4198	26.0239	21.8332	13.1436	13.4564
Skewness	0.1464	0.2069	-0.0134	-0.4323	-0.2527	0.0555	0.2355	0.1211
Kurtosis	9.0624	2.6628	1.0834	1.3779	4.2729	1.6133	1.3825	3.2967
n	1494	1814	1135	364	108	145	247	319
Jarque-Bera	2293.21 **	21.53 **	173.76 **	51.24 **	8.44	11.69 *	29.21 **	1.95
Shapiro-Wilk	0.8095 **	0.9758 **	0.9684 **	0.9799 **	0.9162 **	0.9722	0.9692 *	0.9364

Table XI
F Tests of Variances

This table contains standard deviation of profits for various trades and F tests comparing them to the standard deviations of calls and puts.
*** and ** represents significance at the 1% and 0.1% level, respectively.**

Panel A: One Week Holding Period			
	SD	v Calls	v Puts
Call	8.4645		1.3327 **
Puts	6.3513	1.3327 **	
Straddles	7.0694	1.1973 *	1.1131
Strangles	6.2586	1.3525 *	1.0148
Call Δ Neutral	2.6681	3.1725 **	2.3805 **
Put Δ Neutral	4.3440	1.9485 **	1.4621 *
Bull	4.0220	2.1045 **	1.5791 **
Bear	2.8595	2.9601 **	2.2211 **
Panel B: One Month Holding Period			
	SD	v Calls	v Puts
Call	17.3471		1.1842 *
Puts	14.6492	1.1842 *	
Straddles	19.3672	1.1165	1.3221 **
Strangles	14.9275	1.1621	1.0190
Call Δ Neutral	8.1801	2.1206 **	1.7908 **
Put Δ Neutral	7.6732	2.2607 **	1.9091 **
Bull	7.3499	2.3602 **	1.9931 **
Bear	6.3140	2.7474 **	2.3201 **
Panel C: Expiration Holding Period			
	SD	v Calls	v Puts
Call	29.9948		1.5364 **
Puts	19.5230	1.5364 **	
Straddles	49.3686	1.6459 **	2.5287 **
Strangles	32.4198	1.0808	1.6606 **
Call Δ Neutral	26.0239	1.1526	1.3330
Put Δ Neutral	21.8332	1.3738 *	1.1183
Bull	13.1436	2.2821 **	1.4854 **
Bear	13.4564	2.2290 **	1.4508 **

Table XII
Distributional Moments for Options Profit Distributions

This table presents the mean, standard deviation, skewness and kurtosis of profit distributions for calls, puts, and straddles segregated by purchases and sales. The Jarque-Bera and Shapiro-Wilk statistics test if the distribution is normal. * and ** represent significance at the 1% and 0.1% level, respectively.

	Calls			Puts			Straddles		
	All	Purchases	Sales	All	Purchases	Sales	All	Purchases	Sales
Panel A: One Week Holding Period									
Mean	0.5335	1.7518 **	-1.0235 **	0.1570	-1.0871 **	1.7807 **	0.2220	0.3967	0.0101
St. Dev.	8.4645	8.4337	8.2550	6.3513	5.8806	6.5776	7.0694	7.0019	7.1535
Skewness	0.7004	2.6192	-1.8707	0.1461	-0.7208	0.8221	-0.0297	-0.9804	1.0563
Kurtosis	8.9540	10.6021	4.3860	4.4194	4.0678	4.1194	2.0812	2.1265	2.3092
n	1016	570	446	1277	723	554	874	479	395
Jarque-Bera	1583.79 **	2024.25 **	295.83 **	111.74 **	96.96 **	91.33 **	30.87 **	91.96 **	81.31 **
Shapiro-Wilk	0.8574 **	0.7783 **	0.8209 **	0.9474 **	0.9355 **	0.9372 **	0.9722 **	0.9428 **	0.9322 **
Panel B: One Month Holding Period									
Mean	1.3236	4.1123 **	-2.4208 **	-0.4580	-2.5588 **	2.1466 **	-0.6560	-3.2671 **	2.3232 *
St. Dev.	17.3471	18.2210	15.3393	14.6492	13.8541	15.1756	19.3672	19.5378	18.7519
Skewness	1.1607	2.3440	-1.6331	0.0117	1.2970	-1.2715	-0.0901	-1.1199	1.2733
Kurtosis	6.9401	6.6640	3.2266	2.3082	4.1006	2.5121	1.6061	0.9077	1.0980
n	1080	619	461	1418	780	638	987	526	461
Jarque-Bera	941.09 **	913.10 **	205.89 **	28.31 **	258.04 **	178.24 **	81.25 **	205.90 **	194.06 **
Shapiro-Wilk	0.8643 **	0.7413 **	0.8423 **	0.9534 **	0.8710 **	0.8757 **	0.9658 **	0.8955 **	0.8568 **
Panel C: Expiration Holding Period									
Mean	0.9378	6.2131 **	-6.1016 **	-0.3842	-6.5675 **	7.5947 **	-0.1886	-3.8029	4.2250
St. Dev.	29.9948	28.2071	30.8735	19.5230	16.9609	19.7267	49.3686	50.7039	47.3635
Skewness	0.1464	2.6052	-2.2217	0.2069	-0.0529	0.1603	-0.0134	-0.6207	0.6334
Kurtosis	9.0624	9.0543	6.6146	2.6628	2.1985	3.9142	1.0834	0.8189	1.0001
n	1494	854	640	1814	1022	792	1135	624	511
Jarque-Bera	2293.21 **	2270.35 **	874.90 **	21.53 **	27.83 **	30.97 **	173.76 **	163.75 **	119.32 **
Shapiro-Wilk	0.8095 **	0.7289 **	0.7728 **	0.9758 **	0.9460 **	0.9390 **	0.9684 **	0.9453 **	0.9487 **

Table XIII
Rankings of Profit Influences

This table contains the expected rankings of influence of DELIGHT, GAMBLE, VENTURE, and DECAY for the various trade types

Trade Type[a]	DELIGHT	GAMBLE VENTURE	THIEF
Panel A: Directional trades.			
Calls	1	2	3
Puts	1	2	3
Call Doubles	1	2	3
Put Doubles	1	2	3
Bull Spreads	1	??	??
Bear Spreads	1	??	??
Panel B: Volatility trades.			
Straddles	2	1	3
Strangles	2	1	3
Call Δ Neutrals	2	1	3
Put Δ Neutrals	2	1	3

[a]Trade types are described in Appendix I

Table XIV
Beta Coefficient Estimates

This table presents the regression estimates of the equation $PROFIT_t = a + b_F DELIGHT_t + b_G GAMBLE_t + b_V VENTUREt + b_T THIEF_t + e_t$ and the associated beta coefficients.
Beta coefficients measure the relative influence of the independent variables on the profit.

Panel A: Directional Trades

	Expiration		One Month		One Week	
	Estimate	Beta Coefficient	Estimate	Beta Coefficient	Estimate	Beta Coefficient
Calls						
DELIGHT	0.9925	0.6072	1.0577	0.8936	1.0846	0.7641
GAMBLE	1.5645	0.6554	1.1381	0.3642	1.1543	0.2265
VENTURE			0.5936	0.1896	0.6981	0.1777
THIEF	1.1989	0.3209	1.0120	0.2472	1.0870	0.0975
n		1428		666		816
Adjusted R-Squared		0.9710		0.9513		0.9272
Puts						
DELIGHT	0.8877	1.2286	1.0203	0.9773	1.0066	0.9576
GAMBLE	1.1165	0.9602	1.2761	0.3884	1.0533	0.1924
VENTURE			0.5533	0.1619	0.7594	0.2096
THIEF	1.3221	0.7292	1.2735	0.2627	1.2878	0.1387
n		1752		910		1029
Adjusted R-Squared		0.9058		0.9579		0.9151
Bull Spreads						
DELIGHT	1.0190	0.7733	1.0881	0.9847	1.0406	0.8951
GAMBLE	1.2992	0.3843	1.6789	0.2900	1.3452	0.2134
VENTURE			0.5312	0.0967	0.4935	0.1123
THIEF	1.0657	0.2346	1.2687	0.1753	1.2999	0.1108
n		244		108		152
Adjusted R-Squared		0.7282		0.9088		0.7867
Bear Spreads						
DELIGHT	1.0571	0.8105	1.0373	0.8538	0.8534	0.8921
GAMBLE	1.1538	0.3484	1.8690	0.2816	1.4026	0.2459
VENTURE			0.6402	0.1065	0.8739	0.2672
THIEF	1.2286	0.2397	1.6001	0.2345	1.2750	0.1827
n		313		145		174
Adjusted R-Squared		0.7650		0.9140		0.7841

Table XIV continued

Panel B: Volatility Trades

	Expiration		One Month		One Week	
			Straddles			
DELIGHT	0.9562	0.2451	1.0121	0.3723	1.0577	0.5171
GAMBLE	1.4420	1.3605	1.1682	0.6420	1.3694	0.5882
VENTURE			0.6772	0.4655	0.7338	0.5018
THIEF	1.1956	0.7731	1.2932	0.4648	1.4464	0.2915
n		1113		599		710
Adjusted R-Squared		0.9084		0.9121		0.8382
			Strangles			
DELIGHT	1.0682	0.4743	1.0839	0.5071	0.9798	0.3357
GAMBLE	1.4249	1.2722	1.2389	0.7044	1.2308	0.5401
VENTURE			0.6086	0.3694	0.7259	0.4601
THIEF	1.3183	0.8730	0.1218	0.5737	1.0939	0.2441
n		355		208		210
Adjusted R-Squared		0.9464		0.9083		0.8367
			Call Delta Neutrals			
DELIGHT	-0.2447	-0.0122	1.0746	0.0816	0.3452	0.0850
GAMBLE	1.7550	1.2662	1.3743	1.1501	1.3312	0.4146
VENTURE			0.5709	0.4233	0.7586	0.6679
THIEF	1.6339	0.8366	1.1531	0.5418	1.0047	0.2271
n		90		46		56
Adjusted R-Squared		0.9005		0.8723		0.7670
			Put Delta Neutrals			
DELIGHT	1.6342	0.1351	1.6293	0.2639	0.0602	0.0083
GAMBLE	1.2362	1.0729	1.0859	0.7191	1.3377	0.5073
VENTURE			0.6826	0.4677	0.9308	0.6180
THIEF	1.3399	0.8811	1.2845	0.5568	1.4280	0.2042
n		122		62		74
Adjusted R-Squared		0.8453		0.8260		0.7556

Figure 1. In a world without any specialization, the distribution of traders among brokers would be random. Each broker would draw similar a proportion of traders from each group.

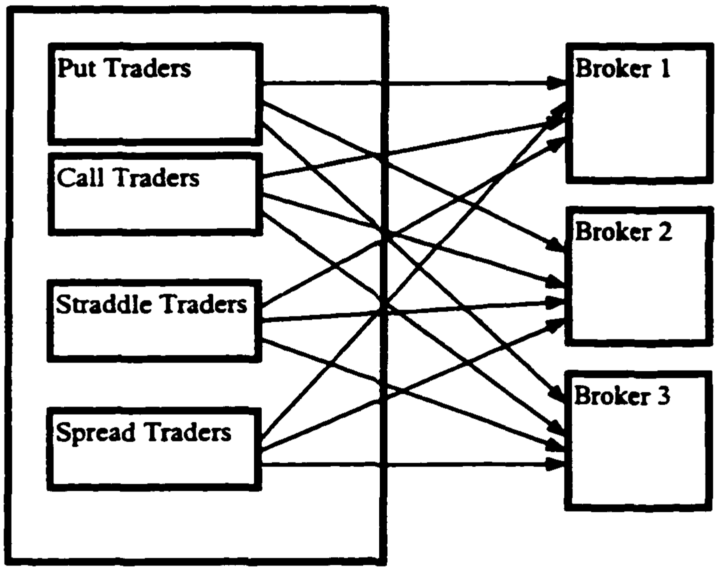


Figure 2. In a world with specialization, certain brokers do a disproportionately large amount of trading in one trade type. The cause of the specialization may be created by the broker or its clients.

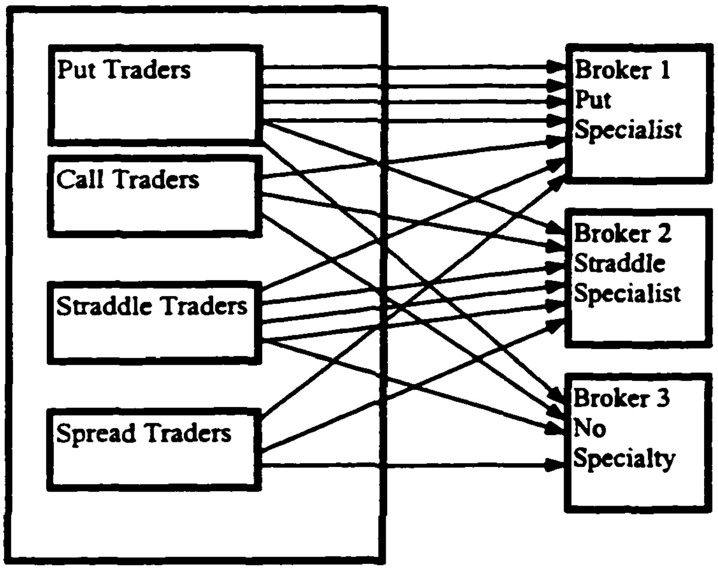
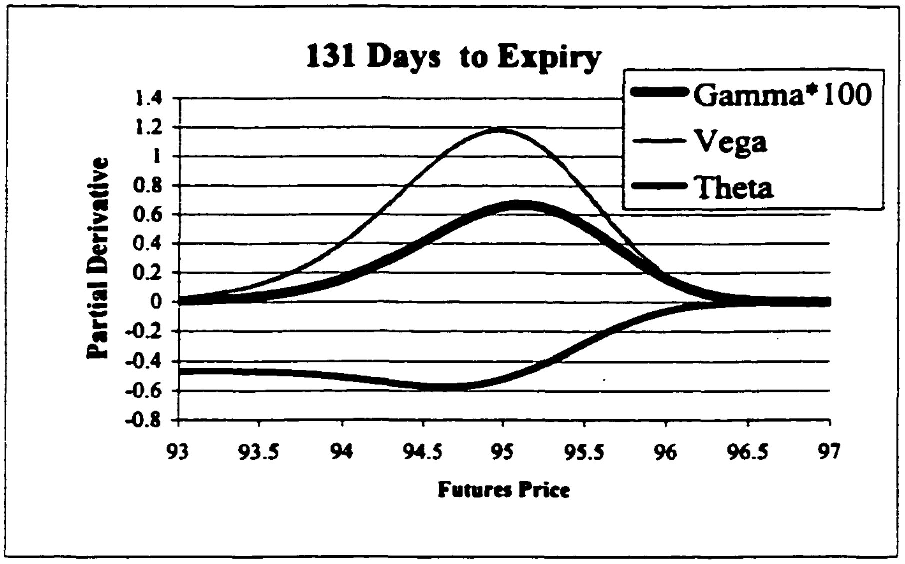


Figure 3
Partial Derivatives for a Call Option

These graphs present the sizes and signs of a call option's vega, gamma, and theta for a range of futures prices. The option has an exercise price of 95, an implied volatility of 20%, and a riskless rate of 3.9%. The times to maturities are the 25th and 75th percentiles of time to expiration in our sample.



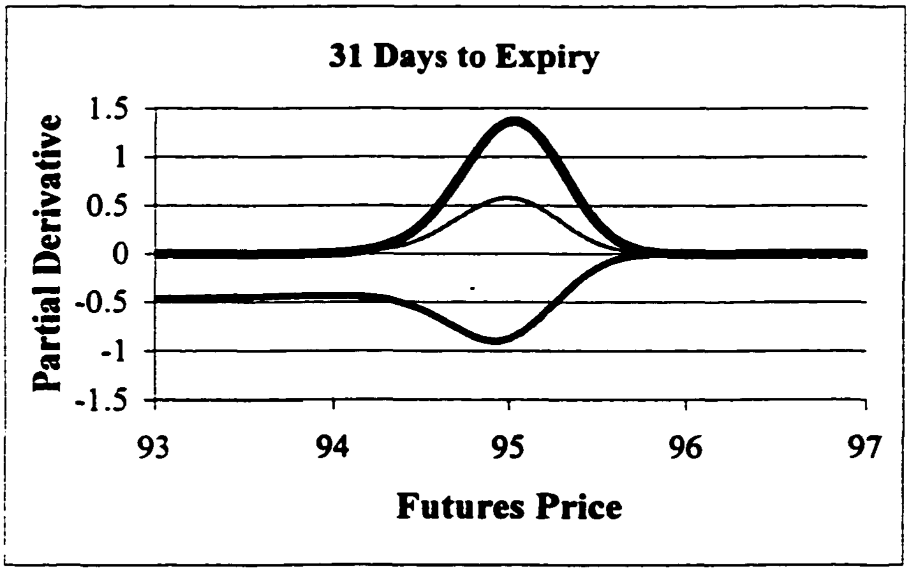


Figure 4
Partial Derivatives for a Strangle

These graphs present the sizes and signs of a strangle's vega, gamma, and theta for a range of futures prices. The strangle has exercise prices of 94.75 and 95.25, an implied volatility of 20%, and a riskless rate of 3.9%. The times to maturities are the 25th and 75th percentiles of time to expiration in our sample.

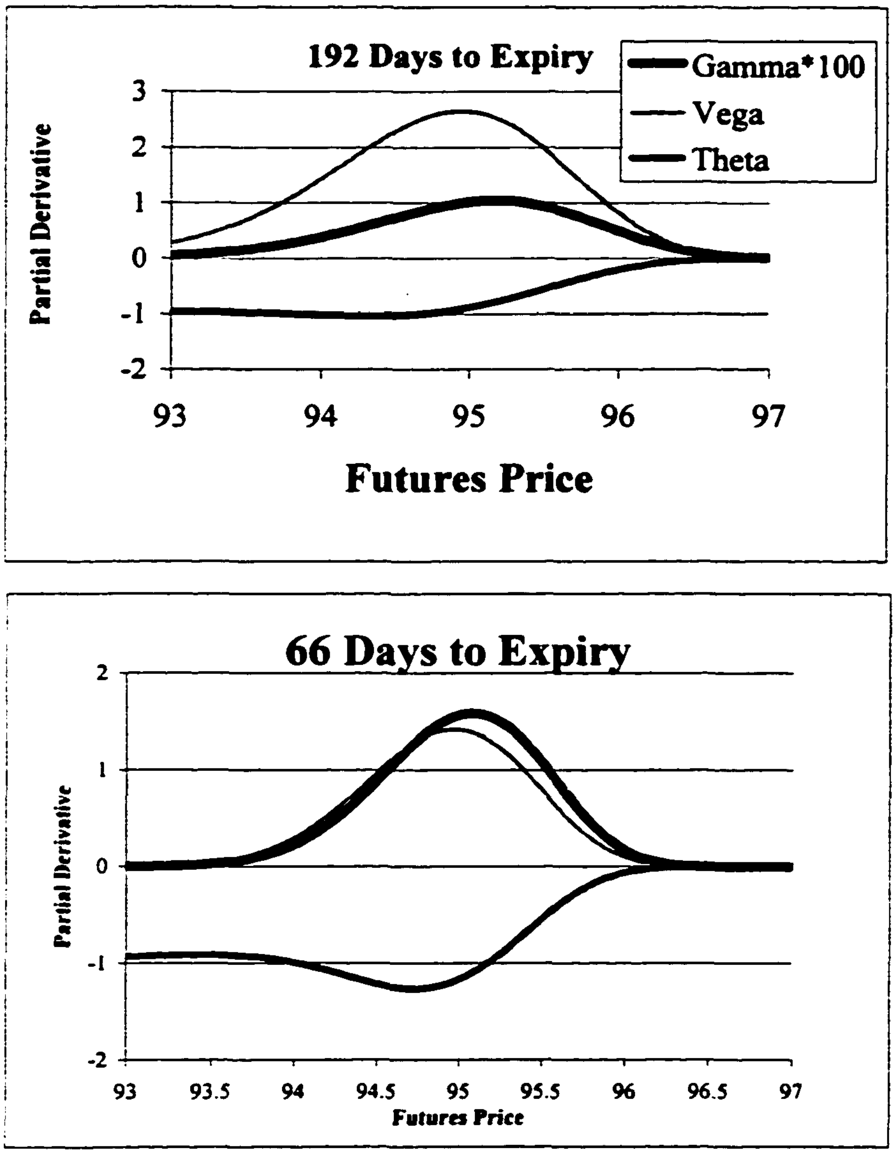
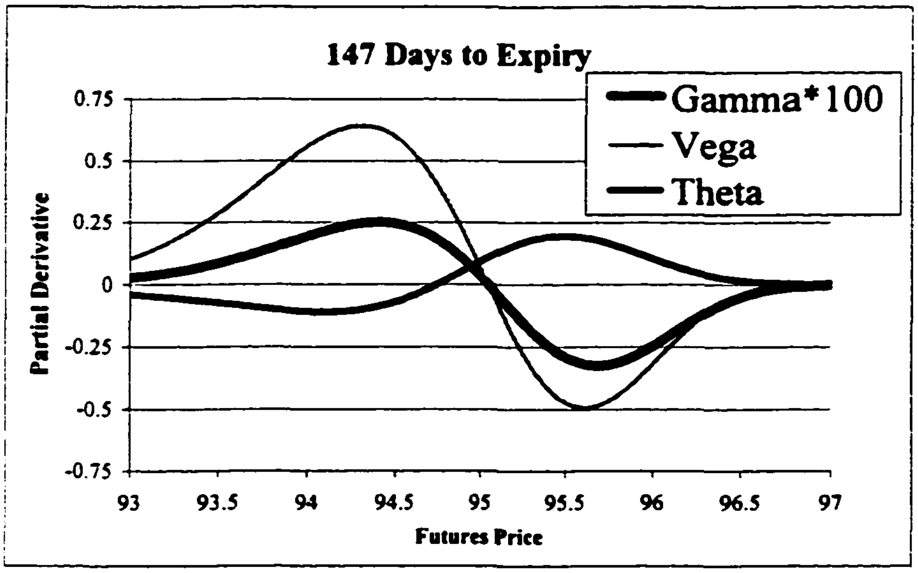


Figure 5
Partial Derivatives for a Bullish Vertical Spread

These graphs present the sizes and signs of a bull spread's vega, gamma, and theta for a range of futures prices. The spread has exercise prices of 94.75 and 95.25, an implied volatility of 20%, and a riskless rate of 3.9%. The times to maturities are the 25th and 75th percentiles of time to expiration in our sample.



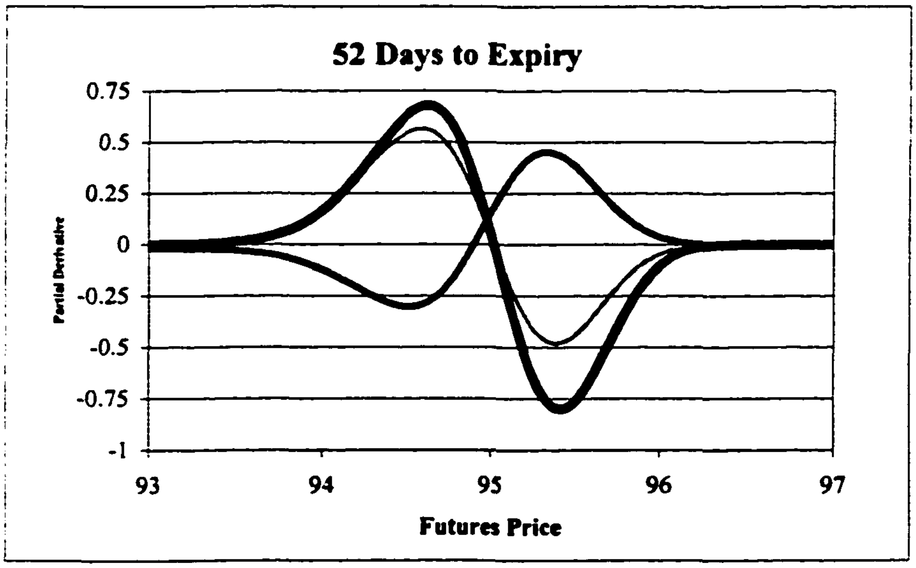


Figure 6
Partial Derivatives for a Put Ratio Spread

These graphs present the sizes and signs of a put ratio spread's vega, gamma, and theta for a range of futures prices. The spread has exercise prices of 94.75 (sold twice) and 95.25 (bought once), an implied volatility of 20%, and a riskless rate of 3.9%. The times to maturities are the 25th and 75th percentiles of time to expiration in our sample.

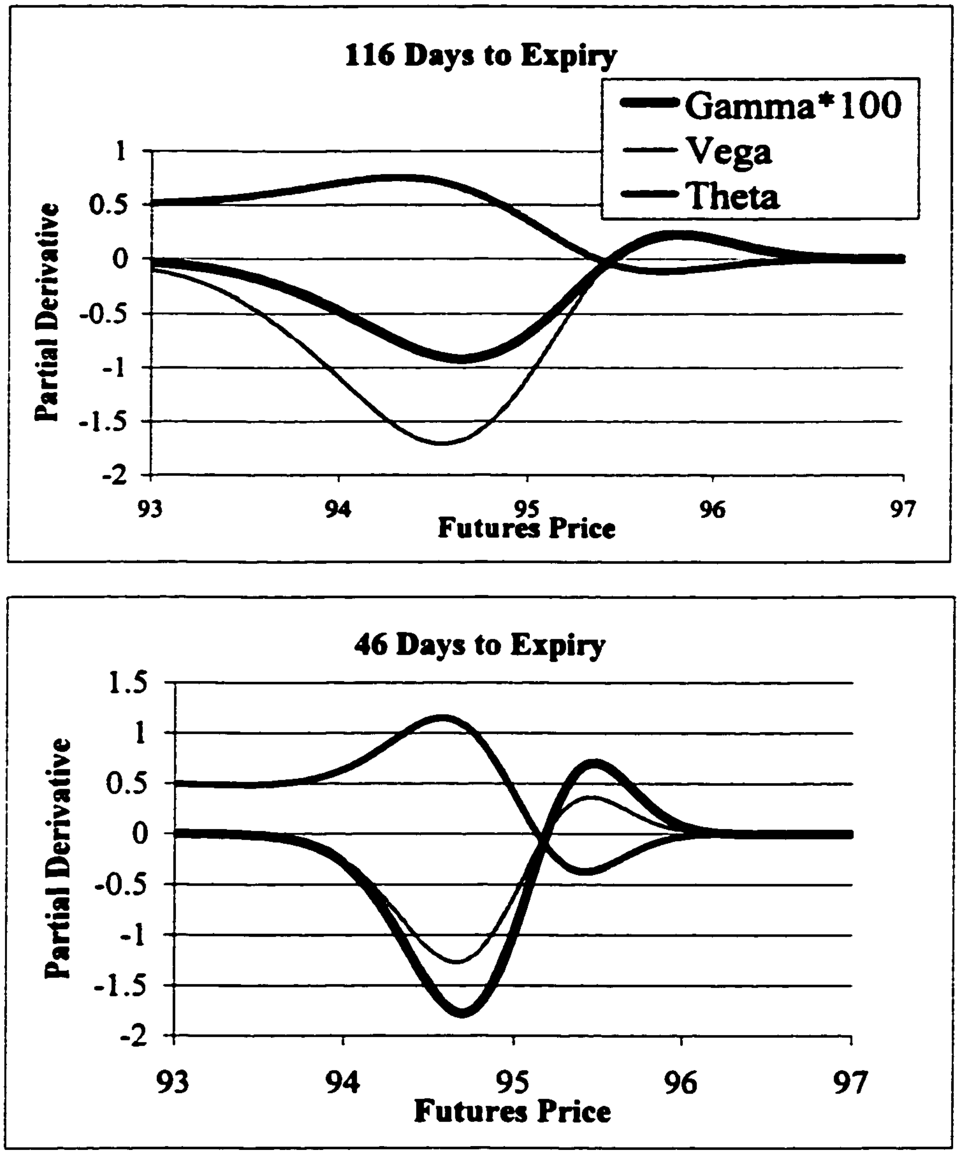
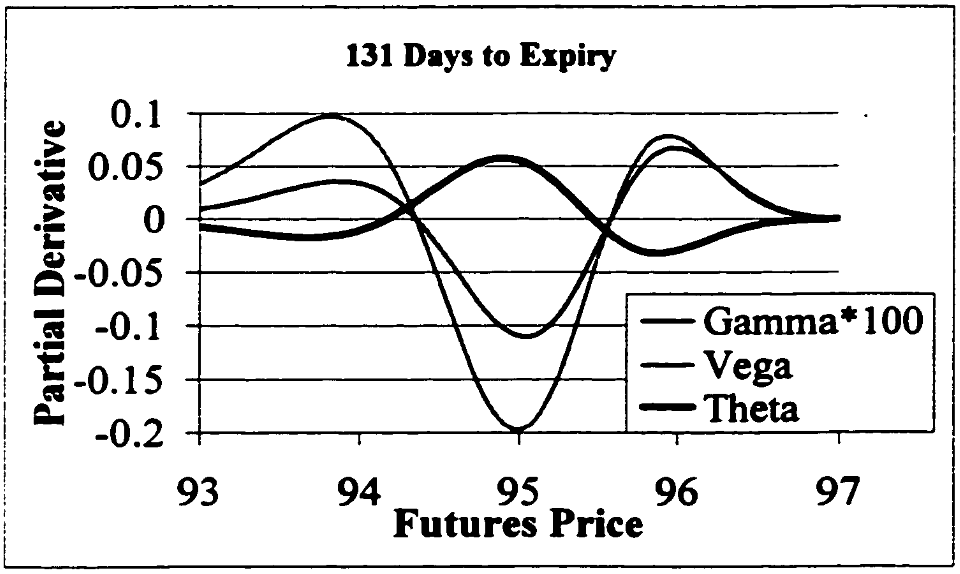


Figure 7
Partial Derivatives for a Butterfly

These graphs present the sizes and signs of a butterfly's vega, gamma, and theta for a range of futures prices. The butterfly has exercise prices of 94.75 (bought once), 95 (sold twice), and 95.25 (bought once), an implied volatility of 20%, and a riskless rate of 3.9%. The time to maturities are the 25th and 75th percentiles of time to expiry in our sample.



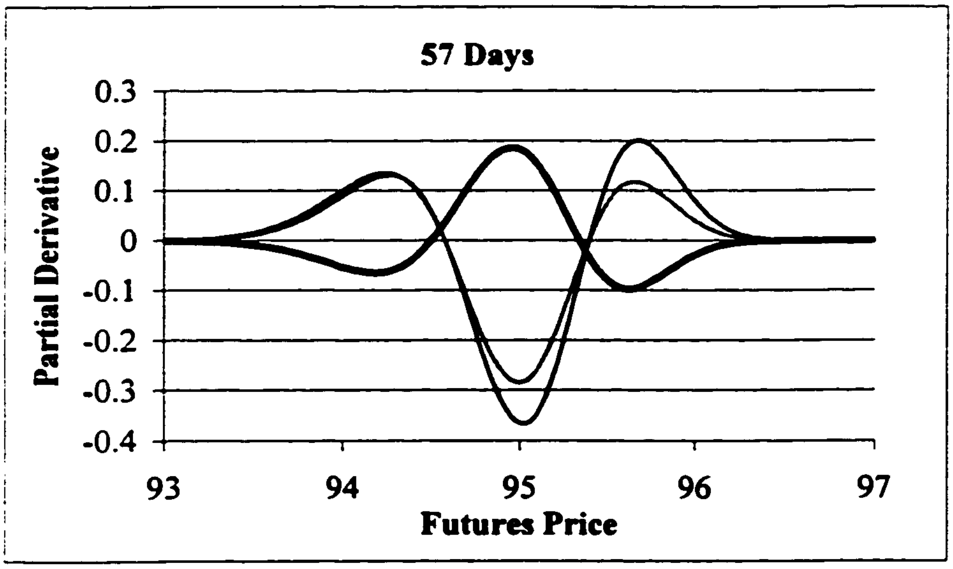


Figure 8
Distributions of Profits over One Month

These figures display the profit distributions for six trade types over a one-month holding period

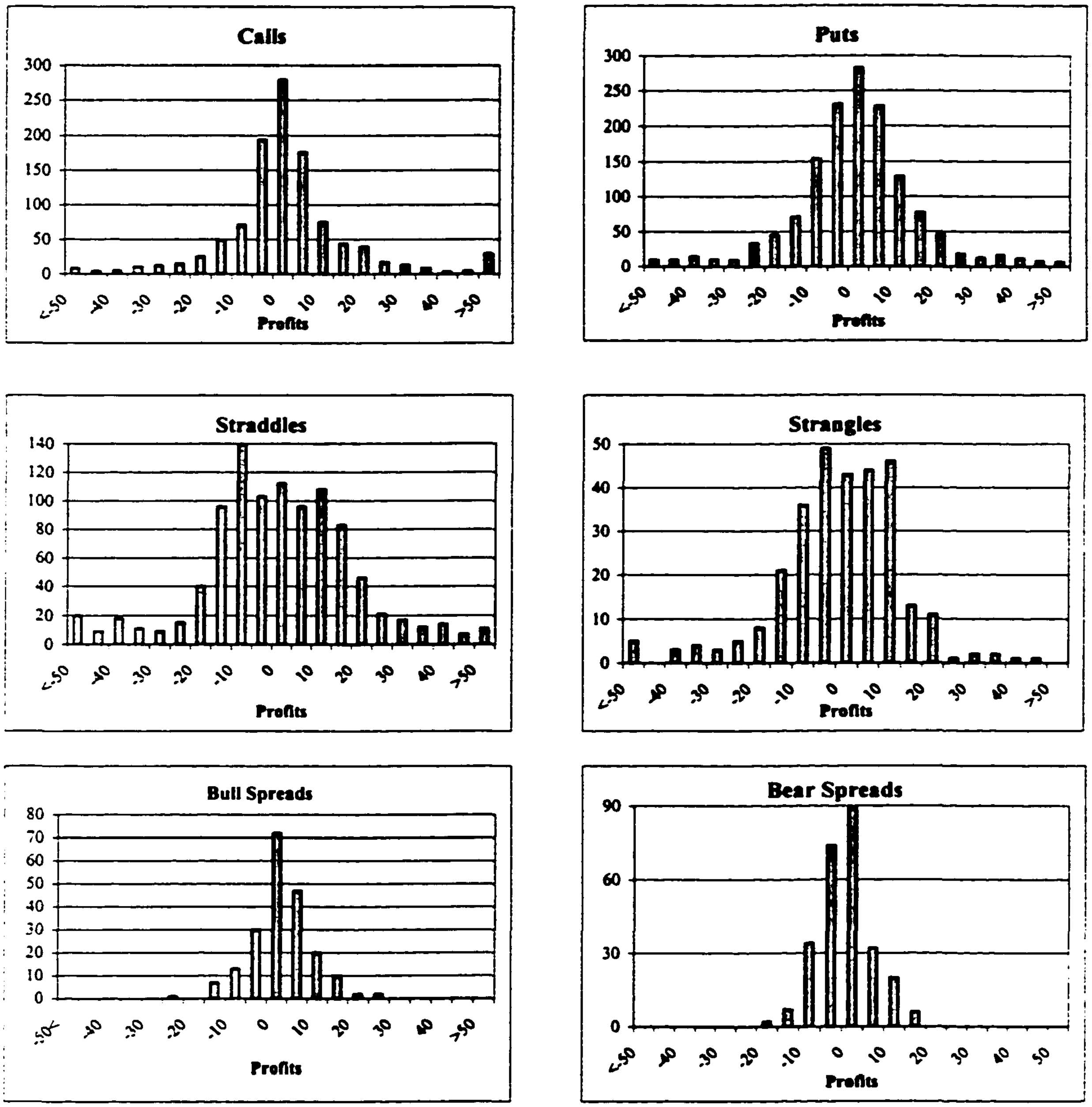
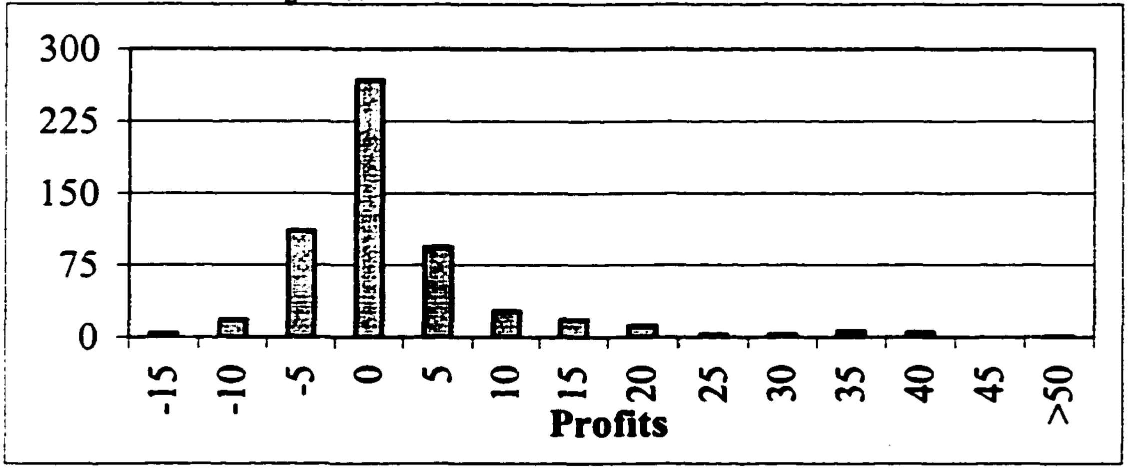


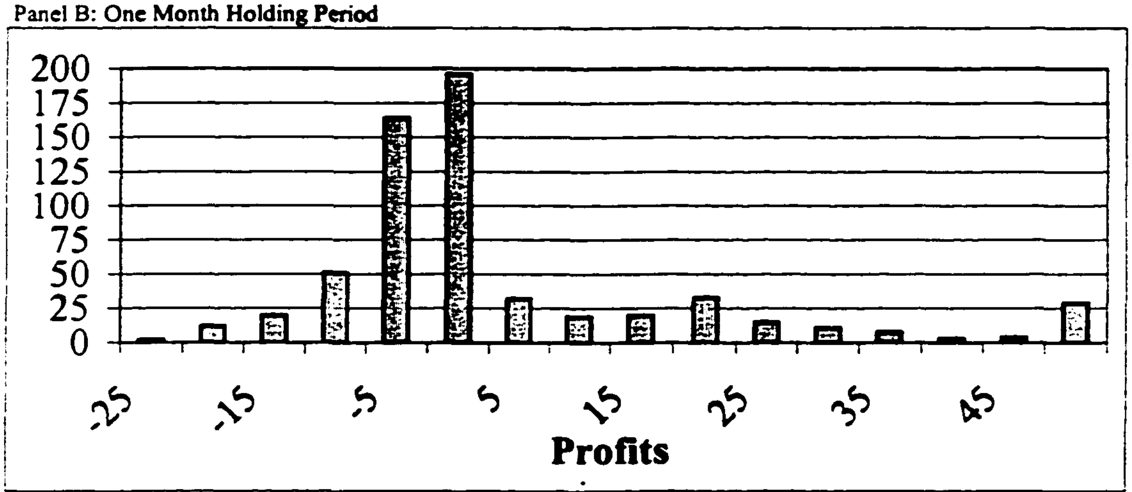
Figure 9
Long Call Profits

These graphs present the distribution of profits for long calls for one week, one month and expiration holding periods. Also presented are the summary statistics for each distribution.

Panel A: One Week Holding Period



Panel B: One Month Holding Period



Panel C: Expiration Holding Period

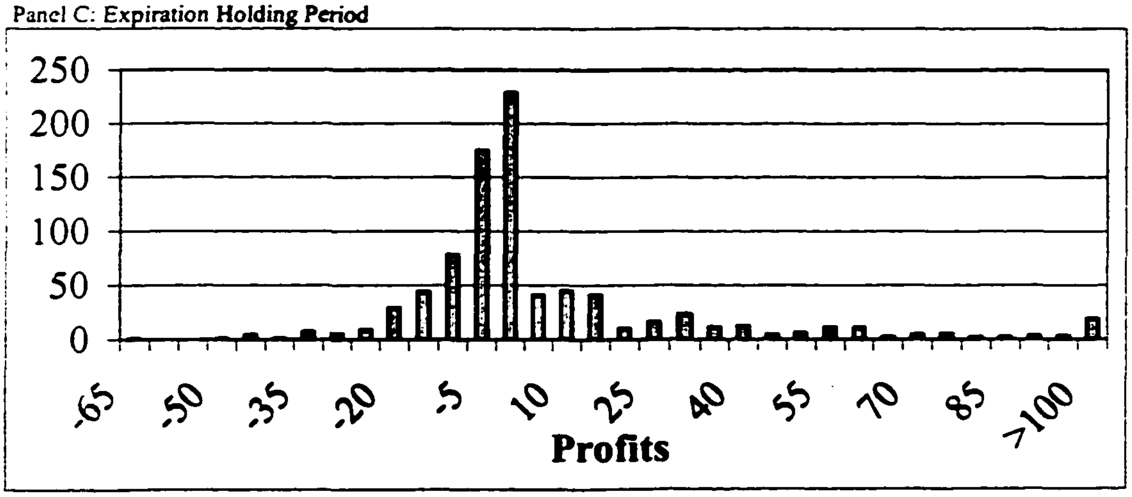
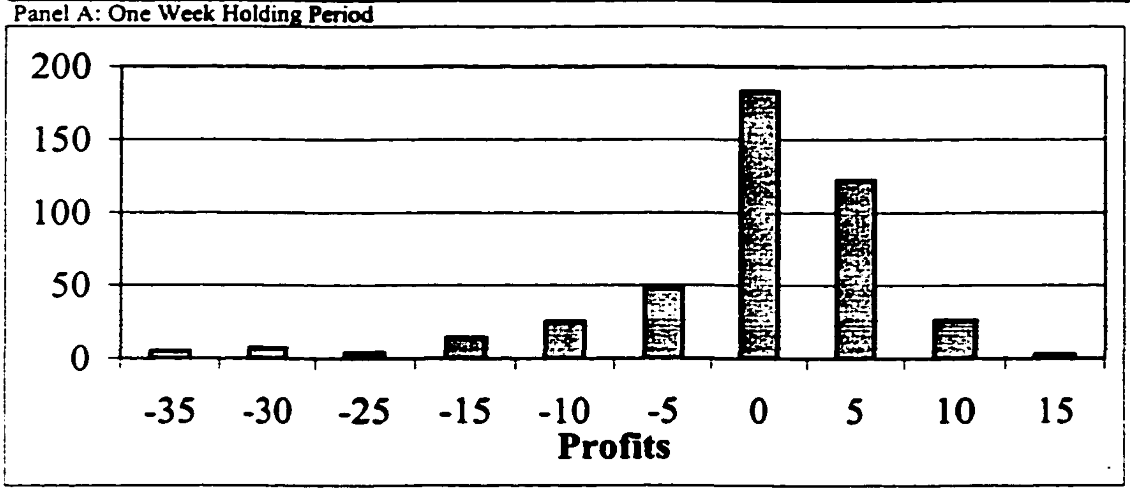


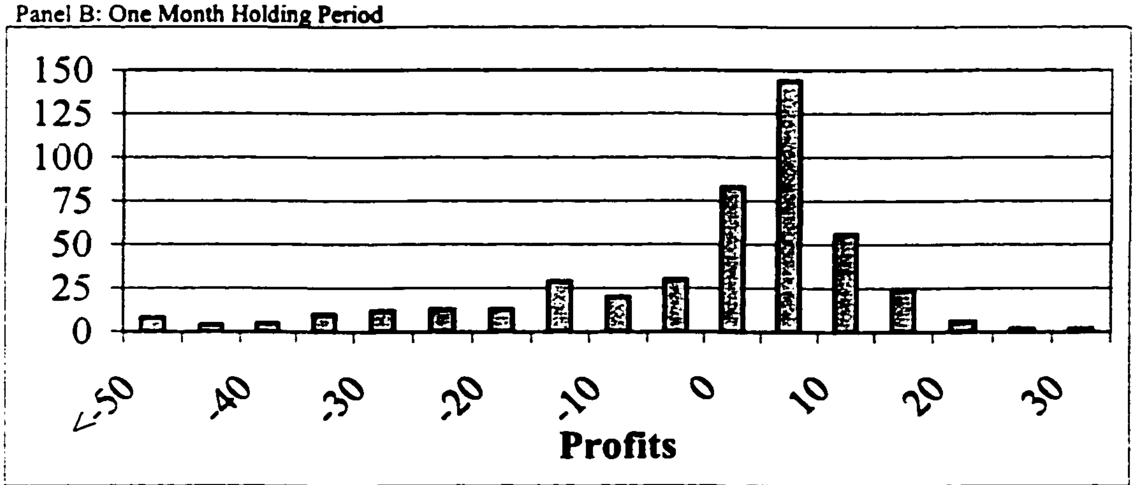
Figure 10
Short Call Profits

These graphs present the distribution of profits for short calls for one week, one month and expiration holding periods. Also presented are the summary statistics for each distribution.

Panel A: One Week Holding Period



Panel B: One Month Holding Period



Panel C: Expiration Holding Period

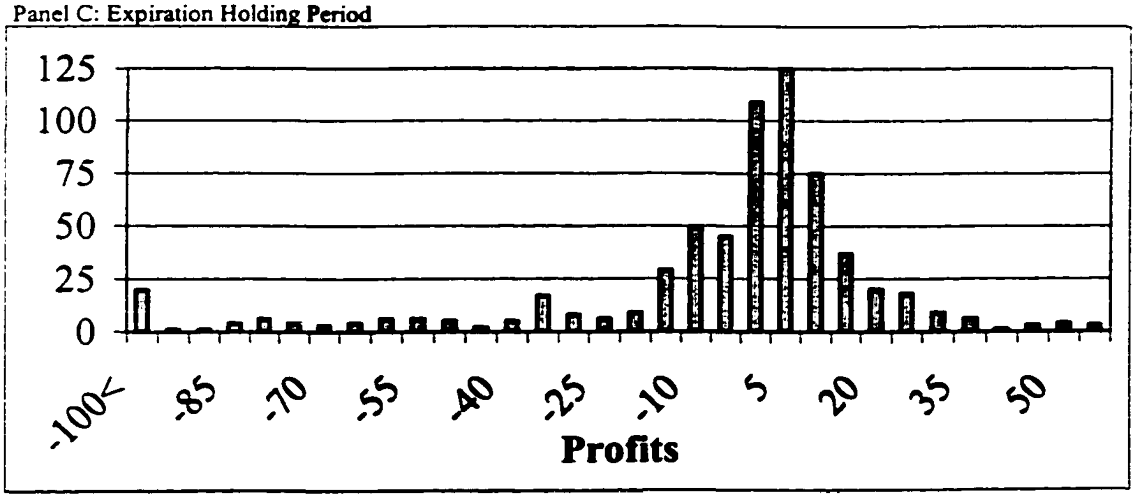
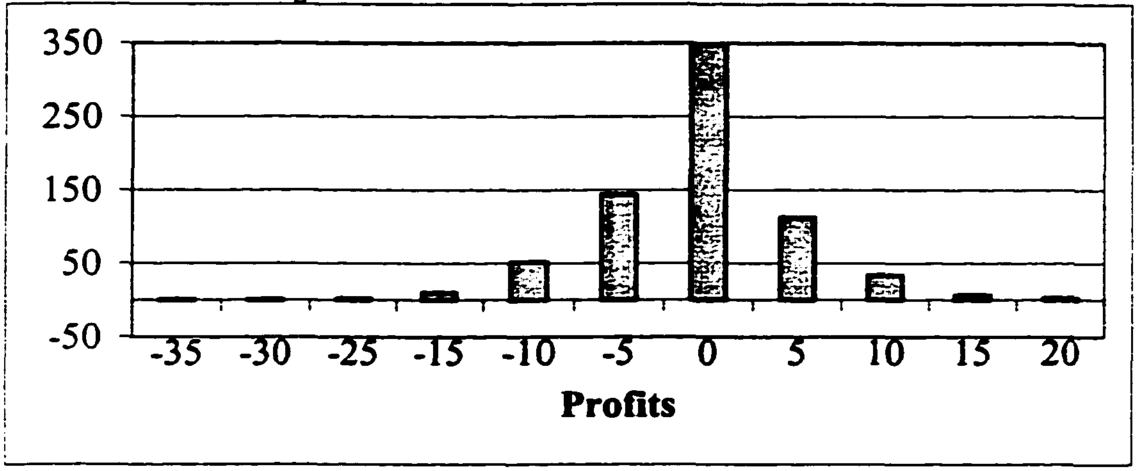


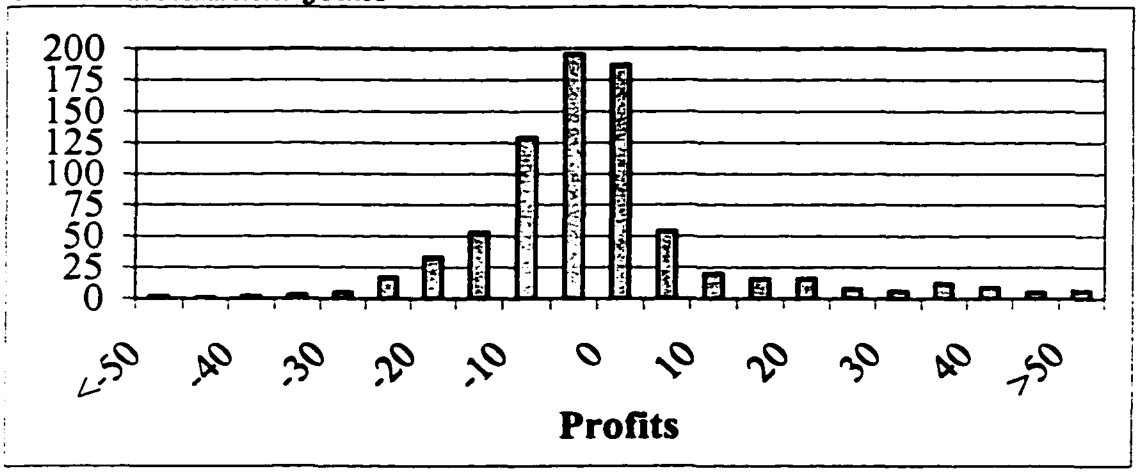
Figure 11
Long Put Profits

These graphs present the distribution of profits for long puts for one week, one month and expiration holding periods. Also presented are the summary statistics for each distribution.

Panel A: One Week Holding Period



Panel B: One Month Holding Period



Panel C: Expiration Holding Period

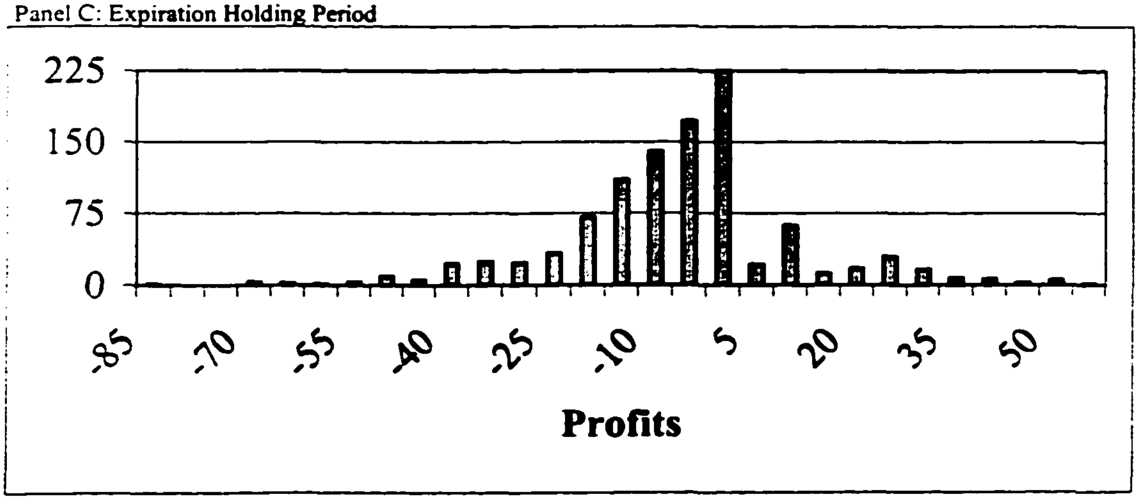
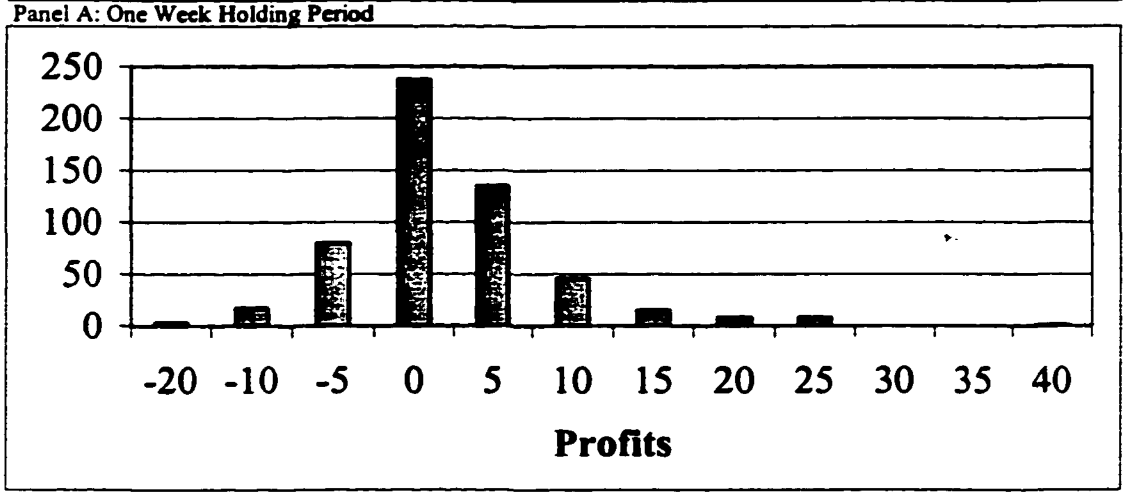


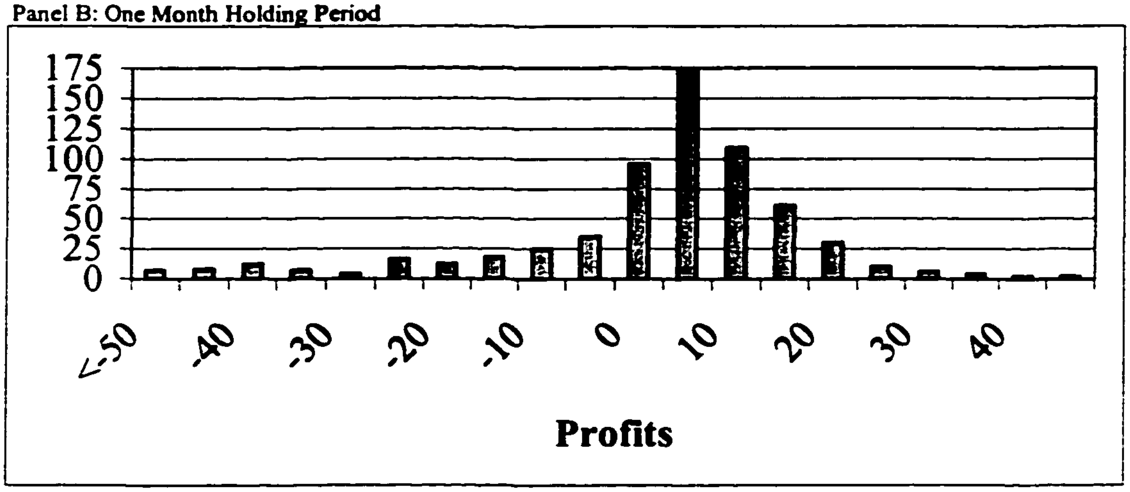
Figure 12
Short Puts Profits

These graphs present the distribution of profits for short puts for one week, one month and expiration holding periods. Also presented are the summary statistics for each distribution.

Panel A: One Week Holding Period



Panel B: One Month Holding Period



Panel C: Expiration Holding Period

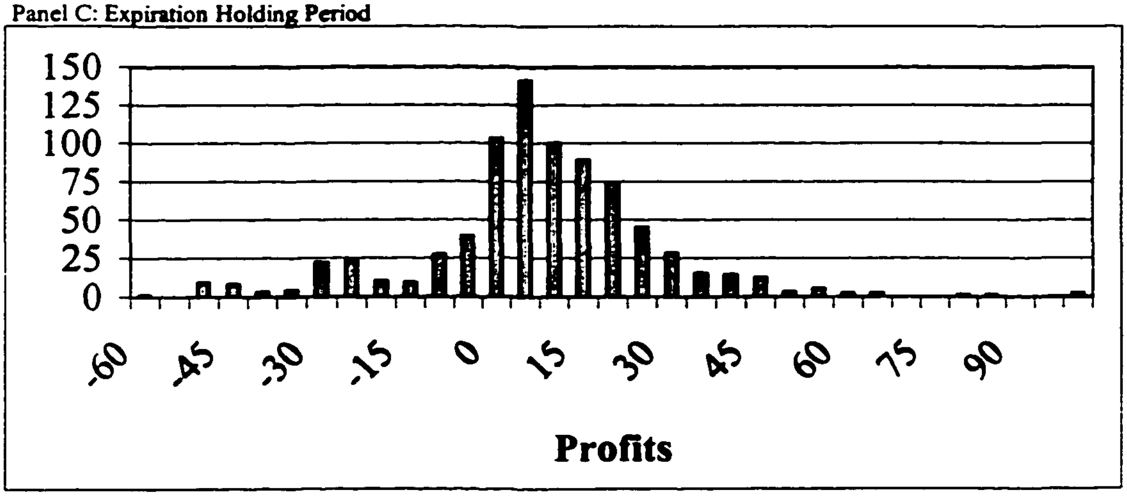
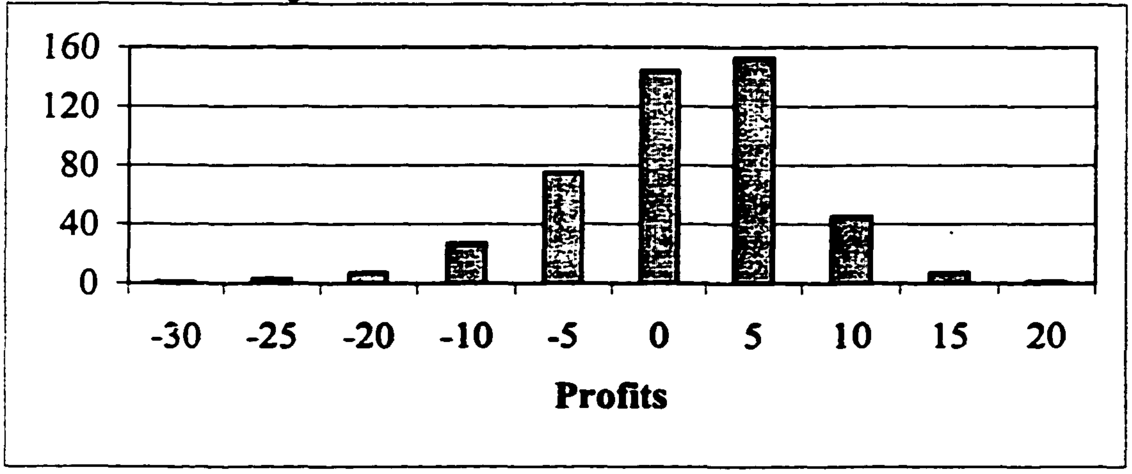


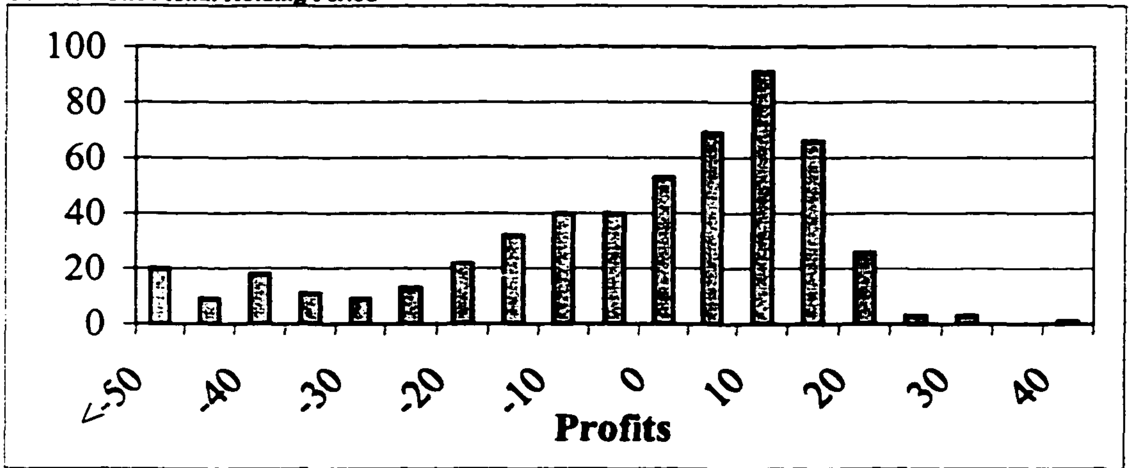
Figure 13
Long Straddle Profits

These graphs present the distribution of profits for long straddles for one week, one month and expiration holding periods. Also presented are the summary statistics for each distribution.

Panel A: One Week Holding Period



Panel B: One Month Holding Period



Panel C: Expiration Holding Period

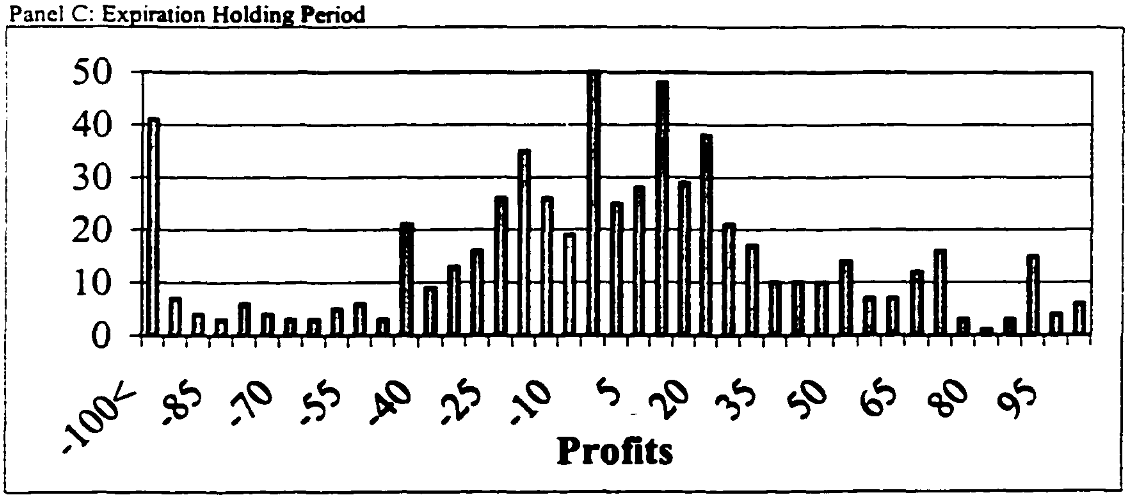
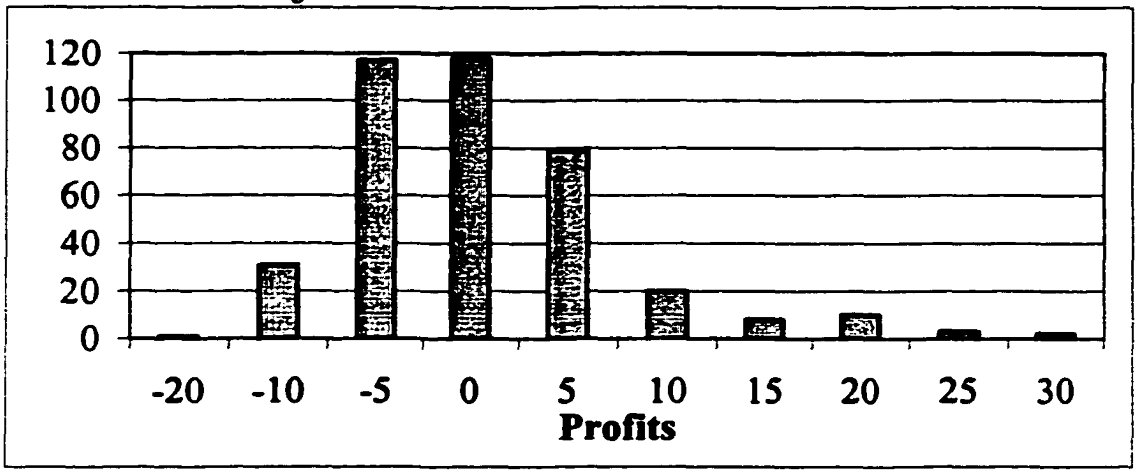


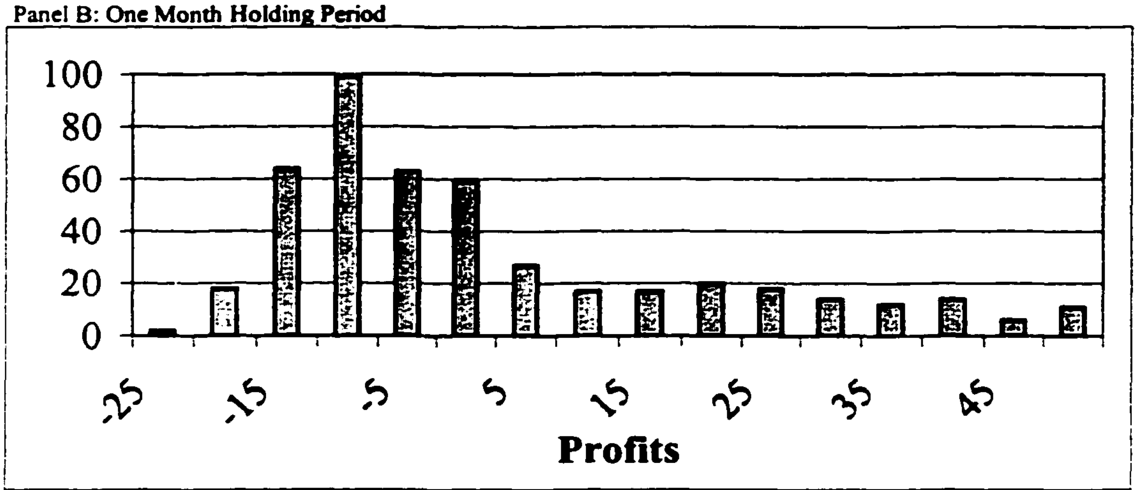
Figure 14
Short Straddle Profits

These graphs present the distribution of profits for short straddles for one week, one month and expiration holding periods. Also presented are the summary statistics for each distribution.

Panel A: One Week Holding Period



Panel B: One Month Holding Period



Panel C: Expiration Holding Period