Clearly Irrational Financial Market Behavior: Evidence from the Early Exercise of Exchange Traded Stock Options

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ABSTRACT

This paper analyzes the early exercise of Chicago Board Options Exchange listed calls by different classes of investors over the 1996-1999 period. We present two main findings. First, there are a large number of early exercises that can be identified as clearly irrational without invoking any model of market equilibrium, and these exercises are not uniformly distributed across the investor classes. Customers of discount brokers and customers of full service brokers both engage in a significant number of irrational exercises while traders at large investment houses exhibit no irrational early exercise behavior. Second, irrational exercise is triggered both by the underlying stock price attaining its highest level over the past year and by the underlying stock having high past returns. Our findings provide evidence that prospect theory is operative in the options market and that it applies differentially across various classes of investors.

It is well-known that in the absence of market frictions it is irrational to exercise American call options early except in some circumstances just before the underlying stock goes ex-dividend. Even in the presence of market frictions, it is possible to identify – without the imposition of any model of market equilibrium – call exercises which are clearly irrational. In this paper, we employ a previously unavailable data set to analyze the rationality of early exercises of Chicago Board Option Exchange (CBOE) calls over the 1996-1999 period by customers of discount brokers (discount customers), customers of full service brokers (full service customers), and traders at large investment houses trading for their firms' own accounts (firm proprietary traders.)

We present two main findings. First, there are a large number of early exercises that can be definitively identified as irrational, and irrational exercise activity is not evenly distributed across the investor classes. Discount customers and full service customers both execute a significant number of irrational exercises. Firm proprietary traders, by contrast, carry out no early exercises which can be shown to be irrational. Second, irrational exercise is triggered for both discount and full service customers by two events. The first event is the underlying stock attaining its highest price level over the past 52 weeks, and the second event is high returns on the underlying stock over any of a number of past time periods. Each of these events triggers irrational exercise by discount and full service customers even after controlling for the other event.

In addition to providing new information on the behavior of different types of option market investors, our results contribute to an important debate over a large body of evidence that has emerged over recent decades which suggests that investors behave irrationally. The

interpretation of this evidence has been controversial, because in almost all cases it can be explained either by investor irrationality or by misspecification of the model of market equilibrium against which the rationality of investor behavior is judged.[1] Our evidence is a noteworthy addition to the existing pool, because the interpretation of it as a manifestation of investor irrationality is not conditional on any model of market equilibrium. Instead, it requires only the very weak assumption that investors prefer more money to less.

Our findings also contribute to a literature (Shefrin and Statman (1985) and Odean (1998)) which maintains that financial market participants behave in accordance with the prospect theory of Kahneman and Tversky (1979). As we will see below, prospect theory predicts that investors are most likely to engage in irrational early exercise behavior after exceeding a reference point or after a large gain. Consequently, our findings on the triggers of irrational early exercise provide evidence that some discount and full service customers exhibit behavior that conforms to prospect theory but fail to provide evidence that any firm proprietary traders behave in accordance with prospect theory. We also examine the triggers of rational early exercise by the investor classes and find that discount and full services customers act in accordance with the predictions of prospect theory while the firm proprietary traders do not. Insofar as we are aware, our evidence is the first that prospect theory is operative in the exchange traded options market and is also the first that it functions differentially across various classes of investors.

Even though we do not test directly for the impact of irrational early call exercise on the prices of securities, our findings have implications for theoretical models which investigate how

[1] See Shleifer (2000) for a review of the evidence and the controversy over its interpretation.

non-standard investor behavior influences the prices of financial assets. Barberis and Huang (2001) show that the high mean of stock returns, their excessive volatility, and the large cross-sectional value premium can be explained by a model in which investors become less cautious about an individual security after that security experiences a gain or surpasses a dynamically determined reference point. Since our analysis shows that real world investors (as opposed to laboratory subjects) behave in this way, our results lend plausibility to the explanation provided in Barberis and Huang (2001) for a number of important stock market anomalies. At the same time, the variation in behavior across investor classes that we document suggests that it would be interesting to extend the representative investor framework of Barberis and Huang (2001) to one that includes heterogeneous agents.

Our findings are also related to those of Finucane (1997) and Heath, Huddart and Lang (1999). Finucane (1997) provides evidence that there are a large number of irrational early exercises of CBOE calls over the 1988-1989 period. We extend his results by investigating the distribution of irrational exercise across investor classes and the events that trigger irrational exercise.[2] Heath, Huddart and Lang (1999) find that the early exercise of executive stock options is also triggered by the underlying stock price reaching a yearly high and by positive returns on the underlying stock. Although the Heath, Huddart and Lang (1999) results are interesting, their interpretation is not straightforward, because an extension of the Black-Scholes model is used as the benchmark for assessing executive exercise decisions. The Black-Scholes benchmark is problematic, because the Black-Scholes model is known to perform poorly even when pricing liquid, European exchange traded options (Bakshi, Cao and Chen (1997).) This poor

[2] We also improve upon Finucane's paper by avoiding two errors in his methodology which will both be seen below to introduce a bias toward misclassifying early exercises as irrational.

performance is exacerbated in the case of executive stock options by long maturities and the fact that executives cannot hedge (or sell) their options. The inability to hedge implies that the individual risk aversion of each executive impacts the value of holding rather than exercising options which is not taken into account by Heath, Huddart and Lang (1999).

The remainder of the paper is organized as follows. The first section discusses the relationship between prospect theory and irrational early exercise behavior. Section two describes the data. The third section develops the procedure that is used to classify early exercises as irrational. Section four presents results on the incidence of irrational exercise behavior and analyzes its distribution across investor classes. The fifth section provides results on stock price patterns that trigger irrational exercise. Section six concludes.

I. Prospect Theory and Irrational Early Exercise

Prospect theory is an experimentally based descriptive model of decision making under uncertainty put forward by Kahneman and Tversky (1979). Prospect theory has three main features. First, agents derive value from gains and losses in wealth from a reference point rather than from absolute levels as in traditional utility theory. Second, people are more sensitive to losses than to gains which is known as loss aversion. Finally, both gains and losses from the reference point exhibit diminishing sensitivity. Panel A of Figure 1 depicts a standard prospect theory value function. The sudden decrease in the slope of the value function at the reference point (i.e., the point where there is no gain or loss) is a reflection of loss aversion. The convexity in the region of losses and the concavity in the region of gains occurs because people are less sensitive to both gains and losses further from the reference point.

Below we will define an early exercise as irrational if an investor would have obtained more money (for certain) by selling the option. Since the standard prospect theory value function has a positive slope across the range of losses and gains, investors who behave in strict accordance with the standard prospect theory value function will never choose a smaller over a larger amount of money. Hence, such investors will never irrationally exercise options early. We can, nonetheless, derive predictions from the standard prospect theory value function about the situations under which investors are most likely to make careless decisions that result in a loss of value. The first situation occurs when the reference point is crossed from below. When the reference point is exceeded, there is a marked decrease in the slope of the value function which entails that an investor would suddenly care significantly less about throwing away a fixed amount of money by executing an irrational early exercise. The second situation occurs when there has been a large gain. After a large gain, the value function has a small positive slope which results in an irrational early exercise causing only a small loss of value for the investor. The upshot is that the standard prospect theory value function predicts that the circumstances under which it is most likely that investors will carelessly execute irrational early exercises are either after a reference point has been exceeded or after a large gain.

Under prospect theory – as under traditional utility theory – the value functions of different investors will vary. We consider two alternatives to the standard prospect theory value function which would result in irrational early exercise (without any carelessness) if investors adhered to them strictly. The slope of the standard prospect theory value function decreases suddenly at the reference point. Panel B of Figure 1 depicts a value function whose slope decreases so markedly at the reference point that it becomes negative in the region of small gains. An investor whose preferences are described by this value function would exercise irrationally

when the reference point is crossed from below. The slope of the standard prospect theory value function reaches its minimum after a large gain.[3] Panel C of Figure 1 depicts a value function that is so concave in the region of gains, that it becomes negatively sloped for large gains. An investor whose preferences are described by this value function would exercise irrationally after a large gain. It should be borne in mind that the value functions depicted in Panels B and C of Figure 1 are both irrational in the sense that they correspond to investors who prefer less to more in the regions where the value functions are negatively sloped. These value functions are, nonetheless, worth considering because they have the potential to provide insight into any irrational exercise behavior that is observed in the market.

II. Data

The main data for this paper were obtained from the CBOE. The data consists of a daily record of exercise and volume activity broken down by different types of investors for all CBOE listed options from the beginning of January 1996 through the end of December 1999. When a CBOE listed option is also listed on another exchange, the data covers exercises and volume for the option from all the exchanges at which it trades. The different types of investors are discount customers, full service customers, and firm proprietary traders. Brokerage houses are assigned to the discount or full service category by an analyst at the CBOE. E-Trade is an example of a discount brokerage house, and Merrill Lynch is an example of a full service brokerage house.

[3] The value function of the standard prospect theory investor may also have a positive slope close to zero after a large loss. We do not expect to observe irrational early exercises in this region, however, because call options are likely to be out-of-the money after a large loss on either the option or the underlying security.

The daily opening, high, low, and closing transaction price for each of the options in the CBOE data set were obtained from Prophet Financial Systems.

The CBOE data contains the ticker symbol for the stock that underlies each option. This ticker symbol is used to extract information on the underlying stock for each option from the Center for Research in Securities Prices (CRSP) files. When a given option observation on a particular trade date cannot be matched with a CRSP stock, it is dropped from the analysis. For each option on each trade date, the information extracted from CRSP on the underlying stock is (1) whether the trade date is an ex-dividend date, (2) the high price for the trade date, (3) the daily closing prices for the previous year (adjusted for splits and stock dividends), and (4) the daily returns for the previous six months.

Altogether there are 74,523 distinct call options in the CBOE database where distinct calls are defined by an underlying stock, strike price, and expiration date. These calls were written on 708 different underlying stocks. Table I contains basic descriptive information on the call options in the sample, the underlying stock price, and the exercise of the calls. Discount customers exercised 4851 distinct call options on distinct trade dates prior to maturity on which the high price of the underlying stock was greater than the strike price. Full service customers had 6458 such exercises, and firm proprietary traders 1834.

III. Classification of Exercises as Irrational

We now turn to the task of identifying irrational option exercises under the weak assumption of non-satiation – that investors prefer more money to less. Although we would like to enumerate criteria that single out exercises as irrational if and only if they violate this

assumption, uncertainty about market imperfections makes this impossible. Consequently, we develop criteria that are satisfied by as many exercises as possible subject to the constraint that every identified exercise almost surely violates non-satiation.

Standard option pricing theory demonstrates that *in the absence of market frictions* it is always irrational to exercise an American call option early except possibly at times immediately prior to the underlying stock going ex-dividend (Hull (2000)). Accordingly, our initial set of candidates for irrational exercises are call option exercises with at least one day left to maturity on days that are not the trade date before an ex-dividend date for the underlying stock.

In the presence of market frictions, it is not necessarily irrational for an investor to exercise a call option early on a trade date that does not precede an ex-dividend date. An investor who exercises a call option may (1) keep the share in his portfolio at least for a short period of time, (2) sell the share immediately to get cash, or (3) use the share to close out a short position in the underlying stock. Since our data do not indicate what investors do with shares obtained from exercise, we will only classify an exercise as irrational if it would be irrational under all three of these alternatives.

In order to evaluate the three possibilities, it is necessary to consider the commissions and taxes associated with the exercise and sale of calls. The commission for exercising a call is equal to the commission for buying at the strike price the number of shares called. No taxes are paid upon the exercise of a call. When the investor disposes of the shares obtained from exercising, however, capital gains taxes are due. If the investor sells the shares, a commission is paid on the sale and capital gains taxes are paid on the difference between the sale price of the shares and the sum of the exercise price and the purchase price of the call. If the investor uses the shares to cover a short position, then capital gains taxes are paid on the difference between the price at

which the shares were shorted and the sum of the exercise price and the purchase price of the call. When the shares obtained from call exercise are used to cover a short position there is no commission beyond that paid for exercising the call. The clock for determining whether the capital gain is short term or long term starts when the call is exercised regardless of whether the shares obtained are sold or are used to cover a short position.

The commission paid when an investor sells a call is, in general, different than the commission paid upon exercise. When a call is sold, capital gains tax is paid on the difference between the sale and the purchase price of the option, and the time that has elapsed between the purchase and the sale is used to determine whether the capital gain is short term or long term. All commissions discussed in this and the previous paragraph are tax deductible.

Using these facts about commissions and taxes, we can analyze the investor's decision to exercise a call. Consider first the possibility that the investor exercises the call early at a time that does not immediately precede the underlying stock going ex-dividend and holds the share obtained in his portfolio for at least one trade date. This strategy is strictly dominated by waiting to exercise on the next trade date. Either way the investor pays the exercise premium and obtains a share of stock. By waiting, however, the investor can earn an extra day of risk free return on his exercise premium and commission. Under both scenarios, no tax is paid at the time of exercise, and the basis for paying tax when the share is eventually sold is the exercise price plus the purchase price of the option.

Consider next the case where the investor exercises the call and then immediately sells the stock to obtain cash. The investor could have chosen instead simply to sell the call. If – after taking account of bid-ask spreads, commissions, and taxes – the investor would have received

more cash from selling the call, then the exercise is irrational. Hence, the exercise decision is irrational if the following inequality is satisfied

$$\begin{aligned} & C_t^{Bid} - \left(C_t^{Bid} - C^{Purch}\right)\tau_t - Comm_t^{Sell\ Call}\left(1-\tau_t\right) \\ & \quad > S_t^{Bid} - K - \left(S_t^{Bid} - K - C^{Purch}\right)\tau_t - Comm_t^{Exercise\ Call}\left(1-\tau_t\right) - Comm_t^{Sell\ Stock}\left(1-\tau_t\right) \end{aligned} \quad (1)$$

where C_t^{Bid} is the price that the call can be sold for at time *t*, C^{Purch} is the price for which the call was purchased at some time before *t*, τ_t is the short term capital gains tax rate at time *t*, S_t^{Bid} is the price that a share of stock can be sold for at time *t*, *K* is the exercise price of the call, and $Comm_t^X$ is the commission for undertaking action *X* at time *t*. The commissions and other quantities are all on a per share basis. The capital gain for exercising the call and then selling the stock is short term, because the investor exercises the call and then immediately sells the stock. The capital gain associated with selling the call will almost always be short term as well, because almost all calls are purchased when their times to expiration are shorter than the period required for a capital gain to be long term. If for a particular exercise the capital gain that would have resulted from selling the call would have been long term, then there is a further disincentive for exercising the call. This disincentive arises, because exercising the call converts a long term capital gain into a short term capital gain. Hence, if assuming that the capital gains tax rate in inequality (1) is the same for both selling or exercising the call introduces any distortion into the assessment of the rationality of exercises, the distortion will be a bias against classifying exercises as irrational. We make this assumption in order to be conservative when deciding whether exercises are irrational.

Using the fact discussed above that the commission for exercising a call is the same as the commission for selling a stock (because the commission on stock trades does not generally vary

with the stock price or depend upon whether the trade is a buy or a sell), straightforward algebra shows that inequality (1) simplifies to

$$C_t^{Bid} - \left(S_t^{Bid} - K\right) > Comm_t^{Sell\ Call} - 2Comm_t^{Sell\ Stock}. \tag{2}$$

If inequality (2) is satisfied, then exercising a call and selling the stock immediately to get cash is irrational. Note that inequality (2) differs from the analogous inequality (3) in Finucane (1997). This is because Finucane incorrectly assumes that the commission for selling an option is the same as the commission for exercising an option. As a result, the right hand side of his inequality is $-Comm^{Sell\ Stock}\left(1-\tau_t\right)$ which can be smaller than our expression and therefore introduce a bias toward classifying exercises as irrational.[4]

Consider finally the case where an investor exercises a call in order to use the stock obtained to cover a short position in the stock. In this case, the exercise is irrational if the investor would have ended up with more money by selling the call and buying the stock to cover the short position. Hence, the exercise decision is irrational if the following inequality is satisfied:

$$\begin{aligned} C_t^{Bid} - S_t^{Ask} - \left(C_t^{Bid} - C^{Purch}\right)\tau_t - \left(S^{Short} - S_t^{Ask}\right)\tau_t - \left(Comm_t^{Sell\ Call} + Comm_t^{Buy\ Stock}\right)\left(1-\tau_t\right) \\ > -K - \left(S^{Short} - K - C^{Purch}\right)\tau_t - Comm_t^{Exercise\ Call}\left(1-\tau_t\right) \end{aligned} \tag{3}$$

where S_t^{Ask} is the price at which a share of stock can be bought at time *t*, S^{Short} is the price at which the share was shorted at some time before *t*, and all other variables are as defined above. Once again making use of the fact that the commission for exercising a call is the same as that for buying a stock, straightforward algebra shows that inequality (3) is equivalent to:

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[4] Note that Finucane's expression is always negative while typical commission levels can result in the right hand side of inequality (2) being positive.

$$C_t^{Bid} - \left(S_t^{Ask} - K\right) > Comm_t^{Sell\ Call}. \quad (4)$$

There is one difference on the left hand side and one difference on the right hand side of inequalities (2) and (4). On the left hand side, inequality (4) has S_t^{Ask} instead of S_t^{Bid}. Since the ask price is higher than the bid price, this difference will make it more difficult to satisfy inequality (4) than inequality (2). On the right hand side, inequality (4) is missing $-2Comm_t^{Sell\ Stock}$. This will also make inequality (4) more difficult to satisfy. Consequently, inequality (4) implies inequality (2) but not vice-versa. As a result, in order to classify an exercise as irrational, we require inequality (4) to be satisfied.[5]

In order to use inequality (4) to classify the rationality of early exercises, we must determine an upper bound on the quantity $Comm_t^{Sell\ Call}$. We did this by surveying commission charges from 37 brokerage houses over our data period and found that the greatest commission charged for selling options was a flat fee of \$40 plus \$2 per contract. This commission implies a maximum commission charge on a per share basis when just one call contract is sold. The corresponding maximum commission is \$0.42 (since each call contract is for 100 shares.) Hence, in order to be conservative we will assume an upper bound on $Comm_t^{Sell\ Call}$ of \$0.42.[6]

Another issue that arises when empirically implementing inequality (4) is that we do not know at what point during the day exercise orders are issued. The Options Clearing Corporation

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[5] Finucane (1997) does not consider the possibility that an investor exercises a call to use the stock obtained to cover a short position. This omission also biases Finucane's procedure toward misclassifying early call exercises as irrational, because it is the situation under which it is least likely that the investor is behaving irrationally (i.e., inequality (4) implies inequality (2) but not vice-versa),

[6] As a robustness check, we also ran the tests below assuming an upper bound increased by 50 cents to \$0.92. This change did not alter any of the main features of our results. It might also make sense to use a lesser upper bound for discount customers and firm proprietary traders. We did not do this, because (1) we are not certain how much to reduce the upper bound for these customers and (2) the results reported in Table II below suggest that lesser upper bounds for these investors would not make much of a difference.

assigns exercised calls to call writers at the end of the day, and the assigned call writers then have a fixed number of business days to deliver the underlying shares. Consequently, if the call owners could not short the underlying stock, then it would always be rational for them to exercise as late in the day as possible in order to retain the option of foregoing exercise if the underlying stock price moves adversely (e.g., to below the strike price) during the remainder of the day. However, since the investors can, in fact, short the underlying asset, it can potentially be rational to simultaneously place an exercise order and short a corresponding number of share at some time other than the end of the day. This pair of actions would lock in a cash flow equal to the difference between the stock price at the time of exercise and the strike price regardless of how the stock price moves subsequently.

Ideally, time-stamped data on C_t^{Bid} and S_t^{Ask} would be available. If this were the case, then we would select the minimum value attained by $C_t^{Bid} - S_t^{Ask}$ at any point during the day to use in inequality (4). For most of our data period, however, time-stamped data is not available on CBOE options. Accordingly, in order to ensure that we do not misclassify any possibly rational exercise as irrational, we set S_t^{Ask} and C_t^{Bid} in inequality (4) to, respectively, the stock's high transaction price during the day, S_t^{High}, and the calls low transaction price during the day C_t^{Low}. The value of S_t^{High} almost certainly reflects a transaction at the ask price, and the value of C_t^{Low} almost certainly reflects a transaction at the bid price. Since the call price will tend to be at its highest value of the day when the stock price is at its highest value, it is likely that the computed value $C_t^{Low} - S_t^{High}$ is smaller than the minimum value during the day of $C_t^{Bid} - S_t^{Ask}$. Consequently, it is improbable that the use of $C_t^{Low} - S_t^{High}$ as a proxy for the minimum value that

$C_t^{Bid} - S_t^{Ask}$ attains during the day will lead to the misclassification of any possibly rational exercises as irrational.

Combining the foregoing considerations on commissions and intraday exercise, we will classify early call exercises on non-ex-dividend trade dates as irrational when they satisfy

$$C_t^{Low} - (S_t^{High} - K) > \$0.42. \quad (5)$$

In order to ensure that stale prices are not used to conclude that an exercise is irrational, we do not classify an exercise as irrational if the closing transaction price for the call or the high price for the underlying stock are not available on the trade date of the exercise. For the same reason, we require that at least 10 contracts of the call were transacted on the trade date of the exercise. Finally, we exclude from the irrational category call exercises that occur on trade dates for which the high stock price is less than the strike price, because these exercises may correspond to data errors.

The discussion below will be facilitated by explicitly stating the conditions that an option exercise on a particular trade date must meet in order for it to be classified as irrational and by defining classes of exercises as irrational or rational in terms of these conditions. An observed option exercise will be classified as irrational if and only if

(C1) The option is a call.

(C2) The call is not at its expiration date.

(C3) It is not the day before an ex-dividend date for the underlying stock.

(C4) Data are available on the daily low transaction price for the call and the daily high transaction price for the underlying stock.

(C5) The daily trading volume for the call is at least 10 contracts.[7]

(C6) The day's high price for the underlying stock exceeds the call's strike price.

[7] Requiring that at least 50 contracts of the call were transacted on the trade date of the exercise does not change any of the main features of our results.

(C7) The following inequality is satisfied: $C_t^{Low} - (S_t^{High} - K) > \$0.42$.

Option exercises that conform to (C1)-(C6) will be referred to as *potentially rational or irrational exercises*. Potentially rational or irrational exercises that also satisfy (C7) will be referred to as *irrational exercises.* Potentially rational or irrational exercises that do not satisfy (C7) will be referred to as *rational exercises*. According to this taxonomy, many exercises will be neither rational nor irrational since many exercises do not satisfy (C1)-(C6). Some of these unclassified exercises may be irrational. It is also possible that because of the conservative way criterion (C7) was developed, exercises which we categorize as rational are, in fact, irrational.

IV. Irrational Exercise Behavior and its Distribution across Investor Classes

This section of the paper analyzes the quantity of irrational exercise behavior in our sample and its distribution across the investor classes. We begin by determining the number of irrational exercises by each class of investors. We then evaluate these numbers by comparing them to the number of rational exercises by each investor class and to the number of opportunities that each investor class had to exercise irrationally.

Our data provide us with the number of contracts exercised by each type of investor on each trade date for each type of call, where a type of call is defined by an underlying stock, a strike price, and an expiration date. When one of the investor classes exercises more than one contract of some type of call on a given trade date, we do not know whether this corresponds to exercise orders from one or more investors. As a result, the unit of analysis for this section of the paper will be a type of call on a particular trade date which we will refer to as a *call-trade date.*

Whenever we observe an investor class exercising a strictly positive number of contracts of some type of call on a trade date, we count that as one exercise for that class of investors on that call-trade date.

To illustrate, suppose that on June 23, 1998, discount customers exercised a total of 25 calls on IBM with a strike price of 40 that expire in July 1998, full service customers exercised none of these calls, and firm proprietary traders exercised a total of 10 such calls. Furthermore, suppose that these exercises conform to (C1)-(C7). We would count this exercise data as one irrational exercise for discount customers, zero irrational exercises for full service customers, and one irrational exercise for firm proprietary traders of the July expiration, 40 strike IBM call on June 23, 1998. Even though we know that there must have been at least two distinct exercise orders (and there may have been as many as 65), we will count this data as one exercise for the investors aggregated together in order to treat consistently the call-trade date as the unit of analysis.

Next we re-write inequality (5) which must be satisfied in order for a call exercise to be classified irrational as

$$C_t^{Low} - (S_t^{High} - K) - \$0.42 > 0 \tag{6}$$

and define the quantity E by

$$E \equiv C_t^{Low} - (S_t^{High} - K) - \$0.42. \tag{7}$$

Exercises are irrational then, if they conform to (C1)-(C6) and E is strictly positive. Table II contains the distribution of E for exercises that satisfy (C1)-(C6) for all investors (Panel A), discount customers (Panel B), full service customers (Panel C), and firm proprietary traders (Panel D). Each panel also contains the distribution of E conditional on $E > 0$ which

corresponds to irrational exercises and conditional on $E \leq 0$ which corresponds to rational exercises.

Panel A of Table II shows that irrational exercise takes place on 191 call-trade dates in our sample. Hence, it is a regular occurrence. This finding is consistent with the results reported in Finucane (1997) for CBOE exercises over the 1988-1989 period. Our results, however, add to what is already known from Finucane (1997), because (as noted in the previous section) his methodology is biased toward misclassifying exercises as irrational. Our results also extend those in Finucane (1997) by breaking down the irrational exercise behavior by classes of investors. Panels B through D of Table II indicate that there are 85 irrational exercises by discount customers, 110 irrational exercises by full service customers, and zero irrational exercises by firm proprietary traders. The raw numbers of irrational exercises show that discount customers and full service customers habitually engage in irrational exercise behavior while firm proprietary traders do not.

Figures 2 and 3 display bar charts of, respectively, the number of rational and irrational exercises as a function of the number of calendar days to expiration for each investor type. A comparison of the figures reveals that rational early exercises are more concentrated near option expiration than irrational early exercises. The more uniform distribution of the irrational exercises with respect to option expiration suggests that some exogenous factors may be triggering irrational exercise. This possibility will be explored in the next section. Figure 3 does not provide a chart for firm proprietary traders, because this class of investors had no exercises that satisfied criteria (C1)-(C7). Omitted analogous charts for all early call exercises (i.e., those where conditions (C3)-(C7) are not imposed) look very similar to those in Figure 2 for the rational exercises.

We assess whether the propensity to exercise irrationally varies across the investor classes in two ways. The first approach examines whether the exercises of one investor class are more likely to be irrational than those of the other classes. To determine whether this is the case, we compute the percentage of potentially rational or irrational exercises that actually are irrational. More specifically, we determine the percentage of exercises that conform to (C1)-(C6) which also satisfy (C7). Panel A of Table III reports for all investors and for each investor type the percentage of potentially rational or irrational exercises that are actually irrational. For all investors, 2.14% of potentially rational or irrational exercises are actually irrational. This percentage is 2.57% for discount customers, 2.32% for full service customers, and zero percent for firm proprietary traders.

Permutation tests were conducted to determine whether the observed differences in the percentages between pairs of investor classes are likely to occur by chance if there is no difference in the true underlying distribution of percentages across pairs of investors. For example, to evaluate the statistical significance of the observed difference in the percentages exercised irrationally by discount customers and full service customers, we begin by pooling together the 3303 call-trade dates on which discount customers exercised and the 4745 call-trade dates on which full service customers exercised. When both discount and full service customers exercised on the same call-trade date, it is included in the pool twice. We then

(1) Randomly choose 3303 call-trade dates (without replacement) from the pool and treat them as the discount customer observations. We treat the other 4745 call-trade dates as the full service customer observations.

(2) Compute the difference of the percentage of observations assigned to discount customers that are irrational and the percentage of observations that are assigned to full service customers that are irrational.

Steps (1) and (2) are repeated 1000 times, and we count the number of times that the difference computed in step (2) exceeds the actual in-sample difference of 0.25%. In the test for the discount customers and the full service customers, the difference was greater than 0.25% 156 times which yields the *p*-value of 0.156 reported in Panel B of Table III. The tests for the other pairs of investors were conducted similarly, and the *p*-values from these tests are also reported in Panel B of Table III.

The permutation tests indicate that the differences in the percentages between discount and full service customers is not statistically significant at conventional levels. It is surprising that the exercises of full service customers who receive professional advice are not less likely to be irrational than those of discount customers who do not receive such advice. In fact, it is puzzling that full service customers are not altogether prevented from making obviously irrational financial decisions by their advisors. The *p*-values in the final column of Panel B of Table III indicate that it is more likely that discount customer and full service customer exercises are irrational than those of firm proprietary traders.

We next test for the likelihood that various investor classes will act on opportunities to exercise either irrationally or rationally. In order to conduct these tests, we define an *irrational exercise opportunity* for an investor class as a call-trade date for which the investor class has strictly positive open interest and for which exercising would satisfy criteria (C1)-(C7). Similarly, a *rational exercise opportunity* for an investor class is defined as a call-trade date for which the investor class has strictly positive open interest and for which exercising would satisfy criteria (C1)-(C6) but would violate criterion (C7).

Panel A of Table IV reports by investor class the number of irrational and rational exercise opportunities, the number of irrational and rational exercises, and the percentage of

irrational and rational exercise opportunities in which exercises were carried out. Panel B of Table IV reports the results of permutation tests for the significance of differences in these percentages across investor classes. Discount customers exercise on 0.035% of their irrational exercise opportunities and full service customers exercise on 0.041% of such opportunities. Firm proprietary traders exercise on none of their 46,261 irrational exercise opportunities. The *p*-values in Panel B indicate that the difference in the percentage between discount and full service customers is not significant while the difference in the percentage between either discount customers or full service customers and firm proprietary traders is statistically significant. Hence, given the opportunity to exercise irrationally, discount and full service customers are significantly more likely to act on it than firm proprietary traders.

Panel A of Table IV indicates that discount customers act on 1.31% of their opportunities to exercise rationally while full service customers act on 1.66% of such opportunities and firm proprietary traders act on 2.69% of rational exercise opportunities. The difference in percentages between each pair of investor types is statistically significant at conventional levels. Accordingly, firm proprietary traders who have the lowest propensity for irrational exercise have the highest propensity for rational exercise.

V. Reference Points, Past Returns, and Irrational Exercise

This section of the paper investigates whether irrational exercise for the various investor classes is triggered by the underlying asset crossing dynamically defined reference points or experiencing a period of positive or negative returns. We address these issues by performing logit regressions where the dependent variable indicates whether an irrational exercise has

occurred and the independent variables either signify whether the price of the underlying stock has crossed a reference point or contain information on the accumulated past returns on the underlying asset. We focus on the price and return paths of the underlying assets rather than that of the calls. We do so, because most options on individual equities are illiquid when expirations are longer than a couple of months so that for most exercises it would be impossible to get reliable past time series of prices or returns on the exercised calls.

In the present context the call-trade date is not an appropriate unit of analysis, because on a given trade date all calls written on the same stock would have exactly the same values for the dependent variables that are defined in terms of the price path of the underlying asset. The resulting multicollinearity would make it difficult to interpret any findings. For this reason, we choose stock-trade dates as the unit of analysis for the regressions where a *stock-trade date* refers to all calls on a given trade date that are written on a particular underlying stock. In the regressions below, we include stock-trade dates only if the investor class under consideration has strictly positive open interest on at least one call written on the underlying stock that conforms to criteria (C1)-(C7) (i.e., whose exercise would be classified as irrational.)

The dependent variable is a dummy variable that is equal to one when an investor class has at least one exercise of a call that satisfies (C1)-(C7) which is written on a specific underlying stock on a particular trade date:

$$Exercise_{ijt}^{Irrational} = \begin{cases} 1 & \text{if investor class } i \text{ exercises a (C1)-(C7) call on stock } j \text{ on trade date } t \\ 0 & \text{if investor class } i \text{ has open interest in but no exercises of these calls} \end{cases} \quad (8)$$

The subscript i denotes either all investors, discount customers, or full service customers.[8]

[8] We do not run the regressions for firm proprietary traders, because this class of investors has no exercises which conform to (C1)-(C7).

The first independent variable is a dummy variable that takes the value one if the closing price of the underlying stock on trade date *t* is strictly higher than any of the daily closing prices of the underlying stock over the past 52 weeks.

$$RefPoint_{jt} = \begin{cases} 1 & \text{if closing price of stock } j \text{ on trade date } t \text{ is a 52 week high} \\ 0 & \text{otherwise} \end{cases} \quad (9)$$

Stock splits and stock dividends are taken into account when computing this variable. The next set of independent variables are cumulative returns on the underlying asset over various time periods prior to the exercise on trade date *t*.

$$RetWeek1_{jt} = \text{Cumulative return on stock } j \text{ for trade dates } t-5 \text{ through } t-1 \quad (10)$$
$$RetWeek2_{jt} = \text{Cumulative return on stock } j \text{ for trade dates } t-10 \text{ through } t-6 \quad (11)$$
$$RetWeek3_{jt} = \text{Cumulative return on stock } j \text{ for trade dates } t-15 \text{ through } t-11 \quad (12)$$
$$RetWeek4_{jt} = \text{Cumulative return on stock } j \text{ for trade dates } t-20 \text{ through } t-16 \quad (13)$$
$$RetMonth2_{jt} = \text{Cumulative return on stock } j \text{ for trade dates } t-42 \text{ through } t-21 \quad (14)$$
$$RetMonth3To6_{jt} = \text{Cumulative return on stock } j \text{ for trade dates } t-126 \text{ through } t-43 \quad (15)$$

We also include a control variable on the right hand side of the regressions. This variable provides a measure of the average cash flow that would be lost from exercising rather than selling each of the *N* option held by investor class *i* on trade date *t* that are written on stock *j* and which satisfy (C1)-(C7):

$$CashFlowLoss_{ijt} = \frac{1}{N\left(S_{jt}^{Close}\right)} \sum_{k=1}^{N} E_{kijt} \quad (16)$$

where S_{jt}^{Close} is the closing price of stock *j* on trade date *t* and E_{kijt} is the value from equation (7) on trade date *t* for the k^{th} option on stock *j* held by investor class *i* that satisfies (C1)-(C7). Scaling by the stock price standardizes the cash flow loss across different stocks.

Now that all of the necessary variables have been defined, we turn to the analysis of the following regression equation:

$$Exercise_{ijt}^{Irrational} = \beta_0 + \beta_1 RefPoint_{jt} + \beta_2 RetWeek1_{jt} + \beta_3 RetWeek2_{jt} + \beta_4 RetWeek3_{jt} + \beta_5 RetWeek4_{jt} + \beta_6 RetMonth2_{jt} + \beta_7 RetMonth3To6_{jt} + \beta_8 CashFlowLoss_{ijt} + \varepsilon_t \quad (17)$$

Descriptive statistics on the variables in equation (17) are provided in Table V.

Table VI presents estimates of this regression equation when all of the investors are aggregated into one class as well as for discount customers and full service customers separately. The estimate on the reference point variable is significantly positive in all three regressions which provides evidence that a 52 week high price for the underlying stock triggers irrational exercise by discount customers and full service customers. This is true even though there are controls for the return of the underlying stock over various periods leading up to the potential exercise and for the cash flow difference between exercising and selling calls.

The discount customer and full service customer regressions both have positive coefficient estimates for all of the past return variables. Four of these six coefficients from each regression are statistically significant at conventional levels and the other coefficients are all close to statistically significant. The positive coefficient estimates are consistent with irrational option exercise by discount customers and full service customers being triggered by positive stock returns over the corresponding past horizons. The triggering effect is present over the various horizons, even after controlling for returns over the other horizons, for the underlying stock price being at its yearly high, and for the cash flow difference between exercising and selling the option.

As explained in Section I above, the standard prospect theory value function predicts that investors are most likely to carelessly execute irrational early exercises either after a reference

point has been exceeded or after a positive gain. Our finding that irrational early exercise is triggered for discount and full service customers by the underlying asset exceeding its 52 week high or by a period of gains on the underlying asset indicates that at least a subset of discount and full service customers behave in accordance with this prediction of prospect theory. An alternative interpretation of these findings is that at least some subset of discount customers and full service customers have prospect theory value functions like those depicted in Panels B and C of Figure 1. According to this interpretation, investors behave in accordance with value functions that sometimes reflect a preference for less over more. To the best of our knowledge, our results provide the first evidence that prospect theory is operative in the exchange traded options market and that it applies differentially to various classes of investors.

Barberis and Huang (2001) incorporate recent experimental evidence that investor cautiousness depends dynamically on prior gains and losses into a theoretical asset pricing model. In particular, they make use of experimental evidence that a loss that is preceded by gains causes a smaller loss in utility than one that is preceded by losses. Barberis and Huang show that combining this dynamic loss aversion with narrow framing in which investors evaluate the gains or losses on each stock in their portfolios separately produces equilibrium stock returns that have high mean, excessive volatility, and a large cross-sectional value premium. Hence, dynamic loss aversion and narrow framing can account for many of the important stock market anomalies. Our findings that irrational early exercise is triggered by the underlying stock price being at its yearly high and by a period of high returns on the underlying asset provide evidence that investors in actual financial markets (as opposed to those in artificial experimental situations) make decisions about individual assets less carefully after a dynamically determined reference point for the asset has been surpassed or after there has been a period of gains for the asset.

Consequently, our findings lend plausibility to the explanation provided in Barberis and Huang (2001) for a number of important stock market anomalies. At the same time, since we do not find that firm proprietary traders become less careful after surpassing a yearly high price or after high past returns, it would be interesting to extend the representative investor framework of Barberis and Huang (2001) to one that also includes agents who do not display dynamic loss aversion or narrow framing.[9]

We next investigate whether the events that trigger irrational option exercise also trigger the option exercises which we classify as rational. In order to explore this issue, we run the logit regressions for stock-trade dates on which an investor class is long options whose exercise would be rational (i.e., is long options that satisfy (C1)-(C6) and that have an E value less than or equal to zero.) In these regressions the $Exercise_{ijt}$ variable is redefined as follows:

$$Exercise_{ijt}^{Rational} = \begin{cases} 1 & \text{if class } i \text{ exercises a (C1)-(C6), } E \le 0 \text{ call on stock } j \text{ on date } t \\ 0 & \text{if class } i \text{ has open interest in but no exercises of these calls} \end{cases} \quad (18)$$

The subscript i denotes either all investors, discount customers, full service customers, or firm proprietary traders. Table VII presents coefficient estimates for the regressions when $Exercise_{ijt}^{Rational}$ is the dependent variable. As for the case of irrational exercises, the discount customers and the full service customers have coefficients on the reference point variable and all of the past returns variables that are positive. Now all of these coefficient estimates are significant at the one percent level with the exception of one of the past return variables for the full service customers which is close to statistically significant. Hence, for discount customers

[9] The Barberis and Huang (2001) model is in discrete time with each time step corresponding to one year. Consequently, their dynamically evolving reference point is set to an asset's value one year ago. The reference point that we investigate, by contrast, is the highest price of the underlying asset over the past year. In light of our

and full service customers the option exercises which we classify as rational are triggered by the same events as the irrational option exercises.

These triggers of rational exercise by discount customers and full service customers are also consistent with prospect theory. To see that this is the case, first note that because of the conservative way that we developed the criteria for classifying exercises, a number of the exercises that we classify as rational may, in fact, be irrational. Insofar as this is the case, investors who behave in accordance with prospect theory may become more careless after exceeding a reference point or after a positive gain, as explained above, and execute irrational exercises that have been misclassified as rational.

Prospect theory also predicts that exercises which are properly classified as rational – those for which an investor receives more cash by exercising than selling the call – will have more of a tendency to occur after a reference point is exceeded or after a period of gains. To understand why this is the case, consider once again the standard prospect theory value function in Panel A of Figure 1. This value function abruptly switches from convex to concave when the reference point is exceeded, and it becomes uniformly more concave (i.e., the convexity decreases or the concavity increases) as one moves from left to right on the figure. As with standard utility functions, investors are risk-seeking when the value function is convex and risk-averse when the value function is concave. Consequently, when investors move from below to above the reference point, *ceterus paribus*, they suddenly switch from preferring risky gambles over certain payments to preferring certain payments over risky gambles. More generally, as the value function becomes less convex or more concave, investors become more risk-averse.

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evidence, it would also be interesting to incorporate a reference point of the highest price over the past year into a continuous time version of the Barberis and Huang model.

Hence, as their level of loss relative to a reference point decreases or their level of gain relative to a reference point increases, their preference for certain payments over risky gambles increases. As a result, prospect theory predicts that investors will have a tendency to trade the risky gamble inherent in holding a call option for the sure payment that is obtained by selling the call or exercising the call and disposing of the called stock when they exceed a reference point or when there is a gain (i.e., a decrease in losses or an increase in gains.) If the exercises we classify as rational are indeed ones for which an investor obtains more cash by exercising the call and disposing of the called stock than by selling the call, then prospect theory predicts that investors will have a greater propensity to engage in rational exercise after a reference point has been exceeded or after a period of gains. Hence, our findings on the triggers of rational exercise by discount customers and full service customers are consistent with these investors behaving in accordance with the standard prospect theory value function.

Next we consider the triggers of rational exercise for firm proprietary traders. The final column of Table VII contains the rational exercise regression estimates for firm proprietary traders. The coefficient on the reference point variable is close to zero and statistically insignificant. This coefficient estimate indicates that – unlike for the other investors – exercise is not triggered for the firm proprietary traders by the underlying asset attaining a yearly high price. The coefficients on the past return variables are all negative and statistically significant. These coefficient estimates indicate that firm proprietary trader exercise is triggered by past negative returns on the underlying asset. This stands in contrast to the discount customers and full service customers whose exercise is triggered by positive returns on the underlying asset. The results on the triggers of rational exercise by firm proprietary traders violate both of the predictions of prospect theory. Hence, the results from the triggers of rational exercise, like those from the

triggers of irrational exercise, indicate that discount customers and full service customers behave in accordance with prospect theory while firm proprietary traders do not.

The last issue that we investigate is the relationship between alternative definitions of the reference point and irrational exercise behavior. Until now the reference point has been taken to be the highest closing pricing of the underlying stock over the previous 52 weeks. Table VIII reports the results of re-running the irrational exercise regressions from Table VI with the reference point set to either 75 percent, 50 percent, or 25 percent of the highest closing price over the previous 52 weeks. In order to conserve space, only the coefficients on the reference point variable are reported. For ease of comparison, the first row of Table VIII reports the coefficients from the previous regressions using the original definition of the reference point variable. The second row reports this coefficient when the reference point variable is set to one if the current stock price is greater than or equal to 75 percent and less than 100 percent of the high closing price of the stock over the past 52 weeks. With this change, each of the coefficient estimates decreases from its estimate under the original definition of the variable and becomes statistically insignificant. This decrease in the coefficient continues when the reference point is redefined as being between 50 percent and 75 percent or between 25 percent and 50 percent of the high closing price of the stock over the past 52 weeks. Consequently, it appears that 100 percent of the high closing price of the stock over the past 52 weeks is the reference point that is being used by the investors.

VI. Conclusion

This paper studies the early exercise of CBOE listed options by customers of discount brokers, customers of full service brokers, and firm proprietary traders over the 1996 through 1999 period. Early exercise activity is interesting, because it provides a setting in which irrational investor behavior can be identified simply by comparing the cash flow from exercising an option to the cash flow from selling it. As a result, it provides an opportunity to investigate the irrational behavior of investors in actual financial markets without making any assumption about a model of market equilibrium.

Our first major finding is that a large number of early exercises can unambiguously be identified as irrational, and irrational early exercise behavior is not uniformly distributed among the various classes of investors. Customers of discount brokers and customers of full service brokers both engage in a significant number of irrational exercises. Traders at large investment houses, on the other hand, exhibit no irrational early exercise behavior. This first finding is a noteworthy addition to the existing pool of evidence on irrational investor behavior, because the interpretation of it as a manifestation of investor irrationality requires only the very weak assumption that investors prefer more money to less.

Our second major finding is that irrational exercise is triggered for discount and full service customers both by the underlying stock price attaining its highest level over the past year and by the underlying stock having high returns over various past periods. Each of these events triggers irrational exercise even after controlling for the other event. Prospect theory predicts that investors are most likely to engage in irrational early exercise behavior after exceeding a reference point or after a large gain. Consequently, our findings on the triggers of irrational early

exercise provide evidence that some discount and full service customers exhibit behavior that conforms to prospect theory but fail to provide evidence that any firm proprietary traders behave in accordance with prospect theory. An examination of the triggers of rational early exercise by the investor classes also suggests that discount and full services customers are prospect theory agents while firm proprietary traders are not. We believe these findings provide the first evidence that prospect theory applies to the options market as well as the first evidence that it operates differentially for various classes of investors.

This paper contains no direct evidence on whether irrational investor behavior influences the prices at which securities trade. The findings do, however, have implications for theoretical models that investigate how nonstandard investor behavior impacts equilibrium asset prices. Barberis and Huang (2001) show that combining dynamic loss aversion with narrow framing in which investors evaluate the gains or losses on each stock in their portfolios separately produces equilibrium stock returns that have high mean, excessive volatility, and a large cross-sectional value premium. Hence, dynamic loss aversion and narrow framing can account for many of the important stock market anomalies. Our findings that irrational early exercise is triggered by the underlying stock price being at its yearly high and by a period of high returns on the underlying asset provide evidence that investors in actual financial markets (as opposed to those in artificial experimental situations) make decisions about individual assets less carefully after a dynamically determined reference point for the asset has been surpassed or after there has been a period of gains for the asset. Consequently, our findings lend plausibility to the explanation provided in Barberis and Huang (2001) for a number of important stock market anomalies. At the same time, the variation in behavior across investor classes that we document suggests that it would be

interesting to extend the representative investor framework of Barberis and Huang (2001) to one that includes heterogeneous agents.

REFERENCES

Bakshi, Gurdip, Charles Cao, and Zhiwu Chen, 1997, Empirical performance of alternative option pricing models, *Journal of Finance* 52, 2003-2049.

Barberis, Nicholas, and Ming Huang, 2001, Mental accounting, loss aversion, and individual stock returns, *Journal of Finance* 56, 1247-1292.

Finucane, Thomas J., 1997, An empirical analysis of common stock call exercise: A note, *Journal of Banking & Finance* 21, 563-571.

Heath, Chip, Steven Huddart, and Mark Lang, 1999, Psychological factors and stock option exercise, *Quarterly Journal of Economics* 114, 601-627.

Hull, John C., 2000, *Options, Futures, & Other Derivatives, 4th Edition* (Prentice-Hall, Upper Saddle River, NJ).

Kahneman, Daniel, and Amos Tversky, 1979, Prospect theory: An analysis of decision under risk, *Econometrica* 47, 263-291.

Odean, Terrance, 1998, Are investors reluctant to realize their losses? *Journal of Finance* 53, 1775-1798.

Shefrin, Hersh, and Meir Statman, 1985, The disposition to sell winners too early and ride losers too long: Theory and evidence, *Journal of Finance* 40, 777-790.

Shleifer, Andrei, 2000, *Inefficient Markets: An Introduction to Behavioral Finance* (Oxford University Press, Oxford).

Table I
Descriptive Statistics on Chicago Board Options Exchange (CBOE) Calls, Call Exercises, and Underlying Stocks, January 1996 – December 1999

This table presents descriptive statistics on CBOE calls, call exercises, and underlying stocks over the period January 1996 – December 1999. Data on call exercises by the investor classes were obtained directly from the CBOE. Data on daily high stock prices, daily stock closing prices, stock returns, and stock splits and dividends are from the Center for Research in Security Prices. Data on daily low options prices are from Prophet Financial Systems. Panel A reports the number of early exercises of distinct call options on distinct trade dates by customers of discount brokers, customers of full service brokers, and firm proprietary traders for which the daily high price of the underlying stock exceeds the call's strike price. The third column of Panel A reports the number of such exercises when it is also the case that at least ten contracts of the call transacted on the trade date of the exercise. Panel B provides descriptive statistics on a number of variables of interest. The first two rows provide information on the number of calls per stock and the daily trading volume per call for all calls on trade dates where there is at least one trade date until expiration. The remaining rows of Panel B are computed for trade dates on which there is an early call exercises for which the daily high price of the underlying stock is greater than the call's strike price. These rows provide descriptive statistics at the time of exercise on the maturity of the calls, the closing call prices, the closing price of the underlying stock, the ratio of the closing price of the underlying stock on the trade date of exercise to its highest closing price over the previous 52 weeks, and the underlying stock's highest transaction price on the day of exercise minus its closing price on the day of exercise.

Table I – *Continued*

Panel A: Number of Early Exercises of Distinct Calls on Distinct Trade Dates by Investor Classes

	Any number of contracts of the call trade on the date of exercise	At least ten contracts of the call trade on the date of exercise
Discount Customer Exercises	4581	3394
Full Service Customer Exercises	6458	4913
Firm Proprietary Trader Exercises	1834	1798

Panel B: Call Option and Underlying Stock Descriptive Statistics

	25^{th} percentile	Median	75^{th} percentile	Mean	Std.
Calls/stock	1	3	6	4.533	5.69
Call trading volume (contracts)	3	10	31	217.95	29376
Maturity at exercise (days)	2	8	22	17.405	27.68
Daily closing call price ($)	5	10.75	24.25	21.062	33.71
Daily closing stock price ($)	25.125	40.5	61.813	45.740	28.84
Closing stock price on day of exercise/ Highest daily closing price over previous 52 weeks	0.767	0.898	0.967	0.842	0.17
Stocks high price minus closing price on exercise date ($)	0.1875	0.438	0.875	0.773	1.41

Table II

Distribution of $E \equiv C_t^{Low} - \left(S_t^{High} - K\right) - \$0.42$ for Chicago Board Options Exchange (CBOE) Call Exercises, January 1996 – December 1999

This table presents the distribution of $E \equiv C_t^{Low} - \left(S_t^{High} - K\right) - \$0.42$ for CBOE call option exercises over the period January 1996 – December 1999 for all investors aggregated together as well as separately for discount customers, full service customers, and firm proprietary traders. Data on call exercises by the investor classes were obtained directly from the CBOE. Data on ex-dividend dates of underlying stocks and daily high stock prices are from the Center for Research in Security Prices. Data on daily low options prices are from Prophet Financial Systems. The option exercises which are included are those for which: (C1) The option is a call; (C2) The call is not at its expiration date; (C3) It is not the day before an ex-dividend date for the underlying stock; (C4) Data are available on the daily low transaction price for the call and the daily high transaction price for the underlying stock; (C5) The daily trading volume for the call is at least ten contracts; and (C6) The day's high price for the underlying stock exceeds the call's strike price. Panel A records the distribution of E, the distribution of E conditional on E being strictly positive, and the distribution of E conditional on E being zero or negative for all investors. Panel B computes these distributions for customers of discount brokers, Panel C for customers of full service brokers, and Panel D for firm proprietary traders.

Table II – *Continued*

E	Obs.	Mean	Std.	Min	1%	10%	25%	50%	75%	90%	99%	Max
Panel A: All Investors												
All	8915	-2.420	4.891	-95.357	-23.170	-4.170	-2.358	-1.420	-0.920	-0.608	0.955	35.580
≤ 0	8724	-2.517	4.862	-95.357	-23.545	-4.295	-2.420	-1.420	-0.920	-0.670	- 0.295	-0.045
> 0	191	2.024	4.092	0.018	0.018	0.080	0.330	0.892	1.830	4.830	26.892	35.580
Panel B: Discount Customers												
All	3303	-2.858	5.409	-95.357	-24.795	-5.483	-2.795	-1.545	-0.920	-0.670	1.080	15.205
≤ 0	3218	-2.967	5.428	-95.357	-25.170	-5.608	-2.858	-1.545	-0.983	-0.670	- 0.233	-0.045
> 0	85	1.274	2.002	0.018	0.018	0.080	0.205	0.642	1.705	2.580	15.205	15.205
Panel C: Full Service Customers												
All	4745	-2.591	5.333	-91.607	-26.420	-4.295	-2.545	-1.545	-0.920	-0.670	1.080	35.580
≤ 0	4635	-2.713	5.280	-91.607	-26.545	-4.420	-2.545	-1.545	-0.983	-0.670	- 0.233	-0.045
> 0	110	2.559	5.043	0.018	0.018	0.142	0.330	0.955	2.205	6.955	26.892	35.580
Panel D: Firm Proprietary Traders												
All	1685	-1.374	1.443	-26.295	-7.420	-2.170	-1.545	-1.045	-0.795	-0.670	- 0.482	-0.233
≤ 0	1685	-1.374	1.443	-26.295	-7.420	-2.170	-1.545	-1.045	-0.795	-0.670	- 0.482	-0.233
> 0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

Table III
Percentage of Potentially Rational or Irrational Chicago Board Options Exchange (CBOE) Call Exercises that are Actually Irrational by Investor Type, January 1996-December 1999

This table reports the percentage of potentially rational or irrational CBOE call exercises by all investors, discount customers, full service customers, and firm proprietary traders that are actually irrational over the period January 1996 – December 1999. Data on call exercises by the investor classes were obtained directly from the CBOE. Data on ex-dividend dates of the underlying stocks and daily high stock prices are from the Center for Research in Security Prices. Data on daily low options prices are from Prophet Financial Systems. Potentially rational or irrational exercises are those exercises which meet the following criteria: (C1) The option is a call; (C2) The call is not at its expiration date; (C3) It is not the day before an ex-dividend date for the underlying stock; (C4) Data are available on the daily low transaction price for the call and the daily high transaction price for the underlying stock; (C5) The daily trading volume for the call is at least ten contracts; and (C6) The day's high price for the underlying stock exceeds the call's strike price. The quantity $E \equiv C_t^{Low} - (S_t^{High} - K) - \$0.42$ is computed for each option exercise that is a potentially rational or irrational, and those for which $E > 0$ are classified as actually irrational. Panel A reports the number of potentially rational or irrational exercises, actually irrational exercises, and percentage of potentially rational or irrational exercises that are actually irrational for all investors as well as for discount customers, full service customers, and firm proprietary traders. Panel B reports the *p*-values from permutation tests for the equality of the percentages reported in Panel A for different investor classes. The *p*-values are the probabilities that the percentages of two investor types are as different as observed under the null hypothesis that there is no difference in the true distributions of the percentages.

Table III – *Continued*

Panel A: Potentially Rational or Irrational Exercises and Actually Irrational Exercises by Investor Types

	All Investors	Discount Customers	Full Service Customers	Firm Proprietary Traders
Potentially Rat. or Irrat. Exercises	8915	3303	4745	1685
Actually Irrational Exercises	191	85	110	0
Percentage Actually Irrational	2.14%	2.57%	2.32%	0%

Panel B: Permutation Test *p*-Values for Differences in Percentage Actually Irrational Exercises for Pairs of Investor Classes

	Discount Customers	Full Service Customers	Firm Proprietary Traders
Discount Customers	X	0.156	0.000
Full Service Customers	X	X	0.000
Firm Proprietary Traders	X	X	X

Table IV
Percentage of Irrational and Rational Chicago Board Options Exchange (CBOE) Exercise Opportunities that Result in Exercise by Investor Type, January 1996-December 1999

This table reports the percentage of irrational and rational CBOE call exercise opportunities that actually result in exercise by discount customers, full service customers, and firm proprietary traders over the period January 1996 – December 1999. Data on call exercises by the investor classes were obtained directly from the CBOE. Data on ex-dividend dates of the underlying stocks and daily high stock prices are from the Center for Research in Security Prices. Data on daily low options prices are from Prophet Financial Systems. First, all options that meet the following criteria are identified: (C1) The option is a call; (C2) The call is not at its expiration date; (C3) It is not the day before an ex-dividend date for the underlying stock; (C4) Data are available on the daily low transaction price for the call and the daily high transaction price for the underlying stock; (C5) The daily trading volume for the call is at least ten contracts; and (C6) The day's high price for the underlying stock exceeds the call's strike price. Next, the quantity $E \equiv C_t^{Low} - (S_t^{High} - K) - \$0.42$ is computed for each option. Those options that meet criteria (C1)-(C6) and have $E > 0$ are defined as irrational exercise opportunities for an investor class if its open interest for the option is greater than zero. Those options that meet criteria (C1)-(C6) and have $E \leq 0$ are defined as rational exercise opportunities for an investor class if its open interest for the option is greater than zero. Panel A presents by investor class the number of irrational and rational exercise opportunities, the number of irrational and rational exercises, and the percentage of irrational and rational exercise opportunities that result in exercise. Panel B reports the *p*-values from permutation tests for the equality of the percentages of pairs of investor

types reported in Panel A for different investor classes. The *p*-values are the probabilities that the

Table IV – *Continued*

percentages of two investor types are as different as observed under the null hypothesis that there is no difference in the true distributions of the percentages.

Panel A: Irrational and Rational Exercise Opportunities that Result in Exercise

	Discount Customers		Full Service Customers		Firm Proprietary Traders	
	Irrational	Rational	Irrational	Rational	Irrational	Rational
Opportunities	243,472	245,622	265,565	278,478	46,261	62,649
Exercised	85	3218	110	4635	0	1685
Percentage	0.035%	1.31%	0.041%	1.66%	0%	2.69%

Panel B: Permutation Test *p*-Values for Difference in Percentages for Pairs of Investor Classes

	Discount Customers		Full Service Customers		Firm Proprietary Traders	
	Irrational	Rational	Irrational	Rational	Irrational	Rational
Discount Customers	X	X	0.126	0.000	0.000	0.000
Full Service Customers	X	X	X	X	0.000	0.000
Firm Proprietary Traders	X	X	X	X	X	X

Table V
Descriptive Statistics for Logit Regression Variables, January 1996-December 1999

This table reports descriptive statistics for variables constructed over the time period January 1996 – December 1999 which will be used in logit regressions. The investors classes that are used in constructing the variables are customers of discount brokers, customers of full service brokers, and firm proprietary traders. Data on call exercises and open interest by the investor classes were obtained directly from the Chicago Board Options Exchange. Data on ex-dividend dates of the underlying stocks and daily high stock prices are from the Center for Research in Security Prices. Data on daily low options prices are from Prophet Financial Systems. The dependent variable, $Exercise_{ijt}^{Irrational/Rational}$, in the logit regressions is a dummy variable that is equal to one when investor class *i* has at least one exercise of an option written on a specific underlying stock *j* on a particular trade date *t* that satisfies: (C1) The option is a call; (C2) The call is not at its expiration date; (C3) It is not the day before an ex-dividend date for the underlying stock; (C4) Data are available on the daily low transaction price for the call and the daily high transaction price for the underlying stock; (C5) The daily trading volume for the call is at least ten contracts; and (C6) The day's high price for the underlying stock exceeds the call's strike price; and (C7/C7') The following inequality is satisfied: $C_t^{Low} - (S_t^{High} - K) > \$0.42 /$ $C_t^{Low} - (S_t^{High} - K) > \$0.42$. That is,

$$Exercise_{ijt}^{Irrational/Rational} = \begin{cases} 1 & \text{if investor class } i \text{ exercises a (C1)-(C6) call on stock } j \text{ on trade date } t \\ & \text{for which } C^{Low} - \left(S^{High} - K\right) > 0 \Big/ C^{Low} - \left(S^{High} - K\right) \le 0 \\ 0 & \text{if investor i has open interest in but no exercises of these calls} \end{cases}$$

Table V – *Continued*

The first independent variable is a dummy variable that takes the value one if the closing price of the underlying stock on trade date *t* is strictly higher than any of the daily closing prices of the underlying stock over the past 52 weeks.

$$RefPoint_{jt} = \begin{cases} 1 & \text{if closing price of stock } j \text{ on trade date } t \text{ is a 52 week high} \\ 0 & \text{otherwise} \end{cases}$$

Stock splits and stock dividends are taken into account when computing this variable. The next set of independent variables are cumulative returns on the underlying asset over various time periods prior to the exercise on trade date *t*.

$RetWeek1_{jt}$ = Cumulative return on stock j for trade dates $t-5$ through $t-1$
$RetWeek2_{jt}$ = Cumulative return on stock j for trade dates $t-10$ through $t-6$
$RetWeek3_{jt}$ = Cumulative return on stock j for trade dates $t-15$ through $t-11$
$RetWeek4_{jt}$ = Cumulative return on stock j for trade dates $t-20$ through $t-16$
$RetMonth2_{jt}$ = Cumulative return on stock j for trade dates $t-42$ through $t-21$
$RetMonth3To6_{jt}$ = Cumulative return on stock j for trade dates $t-126$ through $t-43$

Finally, there is a control variable. This variable provides a measure of the average cash flow that would be lost from exercising rather than selling each of the *N* option held by investor class *i* on trade date *t* that are written on stock *j* and which satisfy (C1)-(C6):

$$CashFlowLoss_{ijt} = \frac{1}{N\left(S_{jt}^{Close}\right)} \sum_{k=1}^{N} E_{kijt}$$

where S_{jt}^{Close} is the closing price of stock *j* on trade date *t*. In this expression $E_{kijt} = C_{kt}^{Low} - (S_t^{High} - K) - \$0.42$ where C_{kt}^{Low} is the lowest daily transaction price of the k^{th} option held on stock *j* by investor class *i* that satisfies (C1)-(C6) and S_t^{High} is the highest daily transaction price of the underlying stock. Panel A computes the descriptive

Table V – *Continued*

statistics for those stock-trade dates for which any investor had open interest on an option that satisfies (C1)-(C6) and for which $C_{kt}^{Low} - (S_t^{High} - K) - \$0.42 > 0$. Panel B computes the descriptive statistics for those stock-trade dates for which any investor had open interest on an option that satisfies (C1)-(C6) and for which $C_{kt}^{Low} - (S_t^{High} - K) - \$0.42 \leq 0$. In all panels, the $Exercise_{ijt}$ variables are constructed from just those stock-trades for which the indicated class of investors has open interest on options that satisfy (C1)-(C6).

Panel A: Irrational Exercise Opportunities

Continuous variables					
	Mean	Standard deviation	25th percentile	Median	75th percentile
RetWeek1	0.014	0.086	-0.030	0.011	0.054
RetWeek2	0.009	0.084	-0.032	0.007	0.048
RetWeek3	0.009	0.083	-0.032	0.007	0.047
RetWeek4	0.008	0.083	-0.033	0.006	0.046
RetMonth2	0.031	0.159	-0.052	0.029	0.110
RetMonth3To6	0.134	0.323	-0.030	0.121	0.277
CashFlowLoss	0.038	0.025	0.020	0.033	0.050

Binary variables			
	Variable equals 0	Variable equals 1	% stock-days when variable equals 1
$Exercise_{ijt}^{Irrational}$, i = Discount Customers	118,412	85	0.07
$Exercise_{ijt}^{Irrational}$, i = Full Service Customers	126,746	110	0.08
$Exercise_{ijt}^{Irrational}$, i = Firm Proprietary Traders	34,519	0	0.00
RefPoint	119,364	10,807	9.05

Table V – *Continued*

Panel B: Rational Exercise Opportunities

Continuous Variables					
	Mean	Standard deviation	25th percentile	Median	75th percentile
RetWeek1	0.019	0.090	-0.027	0.015	0.061
RetWeek2	0.012	0.085	-0.030	0.009	0.051
RetWeek3	0.010	0.085	-0.031	0.007	0.049
RetWeek4	0.009	0.084	-0.032	0.006	0.047
RetMonth2	0.031	0.162	-0.052	0.029	0.112
RetMonth3To6	0.115	0.327	-0.049	0.108	0.264
CashFlowLoss	-0.027	0.023	-0.035	-0.021	-0.013

Binary variables			
	Variable equals 0	Variable equals 1	% stock-days when variable equals 1
$Exercise_{ijt}^{Rational}$, i = Discount Customers	113,281	2754	2.43
$Exercise_{ijt}^{Rational}$, i = Full Service Customers	123,812	3815	3.08
$Exercise_{ijt}^{Rational}$, i = Firm Proprietary Traders	38,466	1558	4.05
RefPoint	119,752	11,888	9.92

Table VI
Logit Regression of Irrational Exercise Opportunities on Explanatory Variables, January 1996-December 1999

$$Exercise_{ijt}^{Irrational} = \beta_0 + \beta_1 RefPoint_{jt} + \beta_2 RetWeek1_{jt} + \beta_3 RetWeek2_{jt} + \beta_4 RetWeek3_{jt} + \beta_5 RetWeek4_{jt} + \beta_6 RetMonth2_{jt} + \beta_7 RetMonth3To6_{jt} + \beta_8 CashFlowLoss_{ijt} + \varepsilon_t$$

This table reports the results of logit regressions over the January 1996 – December 1999 time period. The columns of the table present the results of estimating the equation for all investors, customers of discount brokers, and customers of full service brokers. Data on call exercises and open interest by the investor classes were obtained directly from the Chicago Board Options Exchange. Data on ex-dividend dates of the underlying stocks and daily high stock prices are from the Center for Research in Security Prices. Data on daily low options prices are from Prophet Financial Systems. The dependent variable, $Exercise_{ijt}^{Irrational}$, is a dummy variable that is equal to one when investor class *i* has at least one exercise of an option written on a specific underlying stock *j* on a particular trade date *t* that satisfies: (C1) The option is a call; (C2) The call is not at its expiration date; (C3) It is not the day before an ex-dividend date for the underlying stock; (C4) Data are available on the daily low transaction price for the call and the daily high transaction price for the underlying stock; (C5) The daily trading volume for the call is at least ten contracts; (C6) The day's high price for the underlying stock exceeds the call's strike price; and (C7) The following inequality is satisfied: $C_t^{Low} - (S_t^{High} - K) - \$0.42 > 0$. That is,

$$Exercise_{ijt}^{Rational} = \begin{cases} 1 & \text{if investor class } i \text{ exercises a (C1)-(C7) call on stock } j \text{ on trade date } t \\ 0 & \text{if investor class } i \text{ has open interest in but no exercises of these calls} \end{cases}$$

Table VI – *Continued*

The first independent variable is a dummy variable that takes the value one if the closing price of the underlying stock on trade date *t* is strictly higher than any of the daily closing prices of the underlying stock over the past 52 weeks.

$$RefPoint_{jt} = \begin{cases} 1 & \text{if closing price of stock } j \text{ on trade date } t \text{ is a 52 week high} \\ 0 & \text{otherwise} \end{cases}$$

Stock splits and stock dividends are taken into account when computing this variable. The next set of independent variables are cumulative returns on the underlying asset over various time periods prior to the exercise on trade date *t*.

$RetWeek1_{jt}$ = Cumulative return on stock j for trade dates $t-5$ through $t-1$
$RetWeek2_{jt}$ = Cumulative return on stock j for trade dates $t-10$ through $t-6$
$RetWeek3_{jt}$ = Cumulative return on stock j for trade dates $t-15$ through $t-11$
$RetWeek4_{jt}$ = Cumulative return on stock j for trade dates $t-20$ through $t-16$
$RetMonth2_{jt}$ = Cumulative return on stock j for trade dates $t-42$ through $t-21$
$RetMonth3To6_{jt}$ = Cumulative return on stock j for trade dates $t-126$ through $t-43$

Finally, there is a control variable. This variable provides a measure of the average cash flow that would be lost from exercising rather than selling each of the *N* option held by investor class *i* on trade date *t* that are written on stock *j* and which satisfy (C1)-(C6):

$$CashFlowLoss_{ijt} = \frac{1}{N\left(S_{jt}^{Close}\right)} \sum_{k=1}^{N} E_{kijt}$$

where S_{jt}^{Close} is the closing price of stock *j* on trade date *t*. In this expression $E_{kijt} = C_{kt}^{Low} - (S_t^{High} - K) - \$0.42$ where C_{kt}^{Low} is the lowest daily transaction price of the k^{th} option held on stock *j* by investor class *i* that satisfies (C1)-(C6) and S_t^{High} is the highest daily transaction price of the underlying stock.

Table VI – *Continued*

	All Traders	Discount Customers	Full Service Customers
Constant	-6.865	-7.613	-7.326
	(50.77)**	(36.22)**	(41.82)**
RefPoint	0.683	0.493	0.921
	(3.60)**	(2.70)*	(3.85)**
RetWeek1	2.358	3.849	1.775
	(3.19)**	(3.77)**	(1.76)
RetWeek2	2.334	2.903	1.823
	(3.16)**	(2.69)**	(1.85)
RetWeek3	2.675	2.904	2.404
	(3.77)**	(2.85)**	(2.52)*
RetWeek4	2.149	1.674	2.377
	(3.01)**	(1.71)	(2.55)*
RetMonth2	1.914	2.047	1.701
	(5.09)**	(3.62)**	(3.44)**
RetMonth3To6	0.417	0.306	0.514
	(2.36)*	(1.45)	(2.22)*
CashFlowLoss	2.218	0.269	2.192
	(0.76)	(0.06)	(0.58)
Observations	128,896	118,497	126,856

Absolute value of z-statistics in parentheses

* significant at 5% level; ** significant at 1% level

Table VII
Logit Regression of Rational Exercise Opportunities on Explanatory Variables, January 1996-December 1999

$$Exercise_{ijt}^{Rational} = \beta_0 + \beta_1 RefPoint_{jt} + \beta_2 RetWeek1_{jt} + \beta_3 RetWeek2_{jt} + \beta_4 RetWeek3_{jt} + \beta_5 RetWeek4_{jt} + \beta_6 RetMonth2_{jt} + \beta_7 RetMonth3To6_{jt} + \beta_8 CashFlowLoss_{ijt} + \varepsilon_t$$

This table reports the results of logit regressions over the January 1996 – December 1999 time period. The columns of the table present the results of estimating the equation for all investors, customers of discount brokers, customers of full service brokers, and firm proprietary traders. Data on call exercises and open interest by the investor classes were obtained directly from the Chicago Board Options Exchange. Data on ex-dividend dates of the underlying stocks and daily high stock prices are from the Center for Research in Security Prices. Data on daily low options prices are from Prophet Financial Systems. The dependent variable, $Exercise_{ijt}^{Rational}$, is a dummy variable that is equal to one when investor class *i* has at least one exercise of an option written on a specific underlying stock *j* on a particular trade date *t* that satisfies: (C1) The option is a call; (C2) The call is not at its expiration date; (C3) It is not the day before an ex-dividend date for the underlying stock; (C4) Data are available on the daily low transaction price for the call and the daily high transaction price for the underlying stock; (C5) The daily trading volume for the call is at least ten contracts; (C6) The day's high price for the underlying stock exceeds the call's strike price; and (C7') The following inequality is satisfied: $C_t^{Low} - (S_t^{High} - K) - \$0.42 \leq 0$. That is,

$$Exercise_{ijt}^{Rational} = \begin{cases} 1 & \text{if investor class } i \text{ exercises a (C1)-(C6) and (C7') call on stock } j \text{ on trade date } t \\ 0 & \text{if investor class } i \text{ has open interest in but no exercises of these calls} \end{cases}$$

Table VII – *Continued*

The first independent variable is a dummy variable that takes the value one if the closing price of the underlying stock on trade date *t* is strictly higher than any of the daily closing prices of the underlying stock over the past 52 weeks.

$$RefPoint_{jt} = \begin{cases} 1 & \text{if closing price of stock } j \text{ on trade date } t \text{ is a 52 week high} \\ 0 & \text{otherwise} \end{cases}$$

Stock splits and stock dividends are taken into account when computing this variable. The next set of independent variables are cumulative returns on the underlying asset over various time periods prior to the exercise on trade date *t*.

$RetWeek1_{jt}$ = Cumulative return on stock j for trade dates $t-5$ through $t-1$
$RetWeek2_{jt}$ = Cumulative return on stock j for trade dates $t-10$ through $t-6$
$RetWeek3_{jt}$ = Cumulative return on stock j for trade dates $t-15$ through $t-11$
$RetWeek4_{jt}$ = Cumulative return on stock j for trade dates $t-20$ through $t-16$
$RetMonth2_{jt}$ = Cumulative return on stock j for trade dates $t-42$ through $t-21$
$RetMonth3To6_{jt}$ = Cumulative return on stock j for trade dates $t-126$ through $t-43$

Finally, there is a control variable. This variable provides a measure of the average cash flow that would be lost from exercising rather than selling each of the *N* option held by investor class *i* on trade date *t* that are written on stock *j* and which satisfy (C1)-(C6):

$$CashFlowLoss_{ijt} = \frac{1}{N\left(S_{jt}^{Close}\right)} \sum_{k=1}^{N} E_{kijt}$$

where S_{jt}^{Close} is the closing price of stock *j* on trade date *t*. In this expression $E_{kijt} = C_{kt}^{Low} - (S_t^{High} - K) - \$0.42$ where C_{kt}^{Low} is the lowest daily transaction price of the k^{th} option held on stock *j* by investor class *i* that satisfies (C1)-(C6) and S_t^{High} is the highest daily transaction price of the underlying stock.

Table VII – *Continued*

	All Traders	Discount Customers	Full Service Customers	Firm Proprietary Traders
Constant	-3.317	-4.308	-3.993	-3.088
	(158.17)**	(134.05)**	(144.52)**	(61.27)**
RefPoint	0.373	0.433	0.437	-0.036
	(9.07)**	(7.42)**	(8.39)**	(0.31)
RetWeek1	2.670	3.298	3.225	-4.298
	(18.31)**	(15.79)**	(17.42)**	(10.61)**
RetWeek2	2.117	2.930	2.384	-2.438
	(14.03)**	(13.60)**	(12.27)**	(5.74)**
RetWeek3	1.420	1.802	1.756	-1.889
	(9.43)**	(8.22)**	(9.08)**	(4.52)**
RetWeek4	1.011	1.378	1.301	-1.621
	(6.73)**	(6.34)**	(6.75)**	(3.89)**
RetMonth2	0.759	0.960	0.900	-0.997
	(9.70)**	(8.36)**	(8.89)**	(4.61)**
RetMonth3To6	0.154	0.367	0.081	-0.510
	(4.21)**	(7.11)**	(1.71)	(4.57)**
CashFlowLoss	-6.403	-7.050	-7.062	2.865
	(13.41)**	(10.63)**	(11.91)**	(1.85)
Observations	131,267	116,035	127,627	40,024

Absolute value of z-statistics in parentheses
* significant at 5% level; ** significant at 1% level

Table VIII
Logit Regression of Irrational Exercise Opportunities on Explanatory Variables Varying Reference Point Variable, January 1996-December 1999

$$Exercise_{ijt}^{Irrational} = \beta_0 + \beta_1 RefPoint_{jt} + \beta_2 RetWeek1_{jt} + \beta_3 RetWeek2_{jt} + \beta_4 RetWeek3_{jt} + \beta_5 RetWeek4_{jt} + \beta_6 RetMonth2_{jt} + \beta_7 RetMonth3To6_{jt} + \beta_8 CashFlowLoss_{ijt} + \varepsilon_t$$

This table reports the results of logit regressions over the January 1996 – December 1999 time period for alternative definitions of a reference point explanatory variable. The columns of the table present the results of estimating the equation for all investors, customers of discount brokers, and customers of full service brokers. Data on call exercises and open interest by the investor classes were obtained directly from the Chicago Board Options Exchange. Data on ex-dividend dates of the underlying stocks and daily high stock prices are from the Center for Research in Security Prices. Data on daily low options prices are from Prophet Financial Systems. The dependent variable, $Exercise_{ijt}^{Irrational}$, is a dummy variable that is equal to one when investor class *i* has at least one exercise of an option written on a specific underlying stock *j* on a particular trade date *t* that satisfies: (C1) The option is a call; (C2) The call is not at its expiration date; (C3) It is not the day before an ex-dividend date for the underlying stock; (C4) Data are available on the daily low transaction price for the call and the daily high transaction price for the underlying stock; (C5) The daily trading volume for the call is at least ten contracts; (C6) The day's high price for the underlying stock exceeds the call's strike price; and (C7) The following inequality is satisfied: $C_t^{Low} - (S_t^{High} - K) - \$0.42 > 0$. That is,

$$Exercise_{ijt}^{Irrational} = \begin{cases} 1 & \text{if investor class } i \text{ exercises a (C1)-(C7) call on stock } j \text{ on trade date } t \\ 0 & \text{if investor class } i \text{ has open interest in but no exercises of these calls} \end{cases}$$

Table VIII – *Continued*

The first independent variable has four different definitions corresponding to the four rows in the table. The four definitions are

$$RefPoint_{jt} = \begin{cases} 1 & \text{if closing price of stock } j \text{ on trade date } t \text{ is a 52 week high} \\ 0 & \text{otherwise} \end{cases}$$

$$RefPoint_{jt} = \begin{cases} 1 & \text{if closing price of stock } j \text{ on trade date } t \text{ is greater than or equal to 75 percent of and less than 100 percent of 52 week high} \\ 0 & \text{otherwise} \end{cases}$$

$$RefPoint_{jt} = \begin{cases} 1 & \text{if closing price of stock } j \text{ on trade date } t \text{ is greater than or equal to 50 percent of and less than 75 percent of 52 week high} \\ 0 & \text{otherwise} \end{cases}$$

$$RefPoint_{jt} = \begin{cases} 1 & \text{if closing price of stock } j \text{ on trade date } t \text{ is greater than or equal to 25 percent of and less than 50 percent of 52 week high} \\ 0 & \text{otherwise} \end{cases}$$

Stock splits and stock dividends are taken into account when computing this variable. The next set of independent variables are cumulative returns on the underlying asset over various time periods prior to the exercise on trade date *t*.

$RetWeek1_{jt}$ = Cumulative return on stock j for trade dates $t-5$ through $t-1$
$RetWeek2_{jt}$ = Cumulative return on stock j for trade dates $t-10$ through $t-6$
$RetWeek3_{jt}$ = Cumulative return on stock j for trade dates $t-15$ through $t-11$
$RetWeek4_{jt}$ = Cumulative return on stock j for trade dates $t-20$ through $t-16$
$RetMonth2_{jt}$ = Cumulative return on stock j for trade dates $t-42$ through $t-21$
$RetMonth3To6_{jt}$ = Cumulative return on stock j for trade dates $t-126$ through $t-43$

Finally, there is a control variable. This variable provides a measure of the average cash flow that would be lost from exercising rather than selling each of the *N* option held by investor class *i* on trade date *t* that are written on stock *j* and which satisfy (C1)-(C6):

$$CashFlowLoss_{ijt} = \frac{1}{N\left(S_{jt}^{Close}\right)} \sum_{k=1}^{N} E_{kijt}$$

Table VIII – *Continued*

where S_{jt}^{Close} is the closing price of stock *j* on trade date *t*. In this expression $E_{kijt} = C_{kt}^{Low} - (S_t^{High} - K) - \$0.42$ where C_{kt}^{Low} is the lowest daily transaction price of the k^{th} option held on stock *j* by investor class *i* that satisfies (C1)-(C6) and S_t^{High} is the highest daily transaction price of the underlying stock.

RefPoint dummy =1 if:	All Traders	Discount Customers	Full Service Customers
(Closing Price)/(52 Week High) ≥ 1	0.683 (3.60)**	0.493 (2.70)*	0.921 (3.85)**
0.75 ≤ (Closing Price)/(52 Week High) < 1	0.222 (1.43)	0.055 (0.24)	0.303 (1.49)
0.50 ≤ (Closing Price)/(52 Week High) < 0.75	-0.827 (3.30)**	-0.353 (1.07)	-1.350 (3.43)**
0.25 ≤ (Closing Price)/(52 Week High) < 0.50	-1.209 (2.35)*	-1.062 (1.45)	-1.396 (1.93)

Absolute value of z-statistics in parentheses
* significant at 5% level; ** significant at 1% level

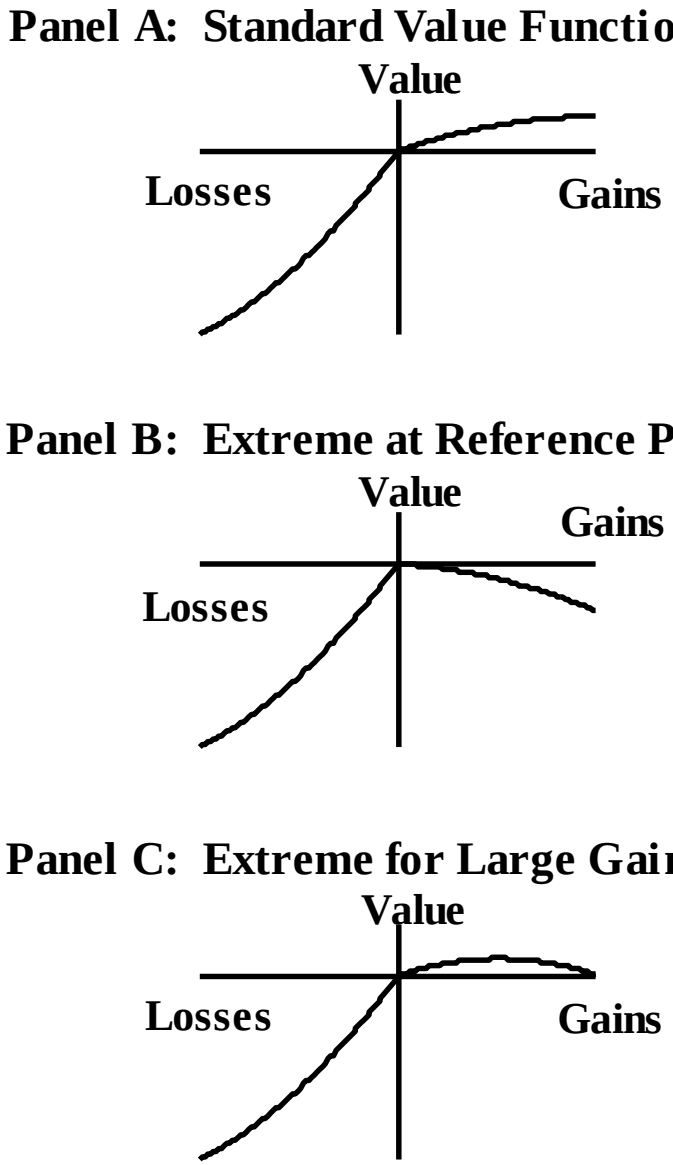
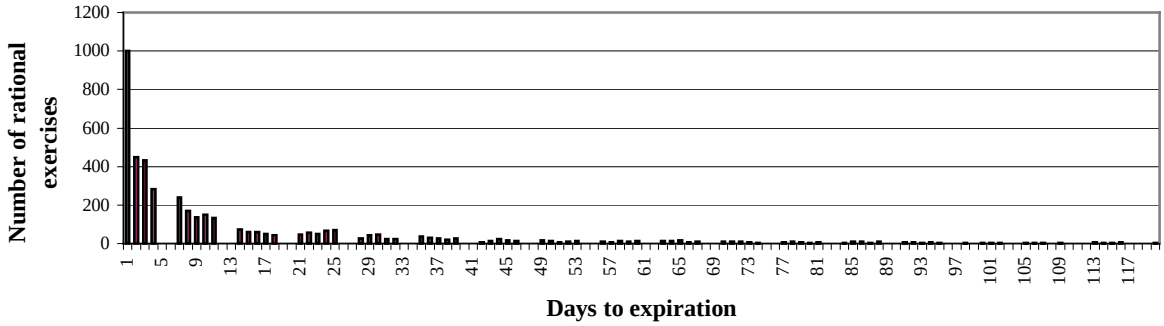
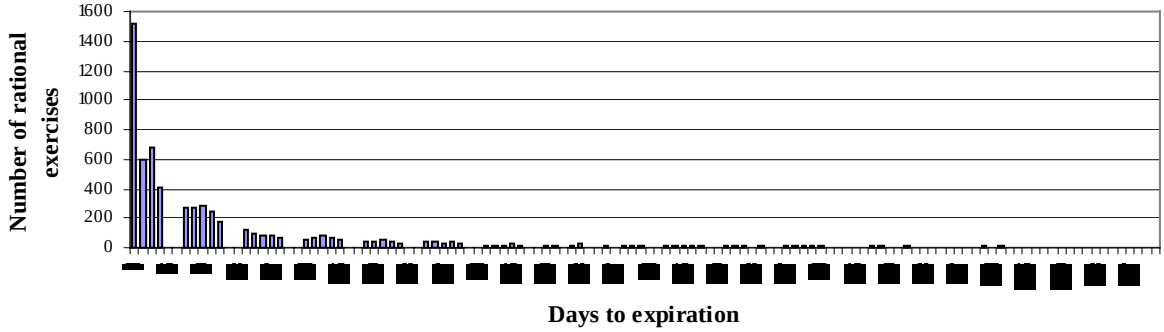


Figure 1. Prospect theory value functions. The top graph depicts a standard prospect theory value function. The middle graph depicts a prospect theory value function with an extreme decrease in slope at the reference point. The bottom graph depicts a prospect theory value function with extreme concavity for large gains.

Panel A: Rational Early Call Exercises by Discount Customers



Panel B: Rational Early Call Exercises by Full Service Customers



Panel C: Rational Early Call Exercises by Firm Proprietary Traders

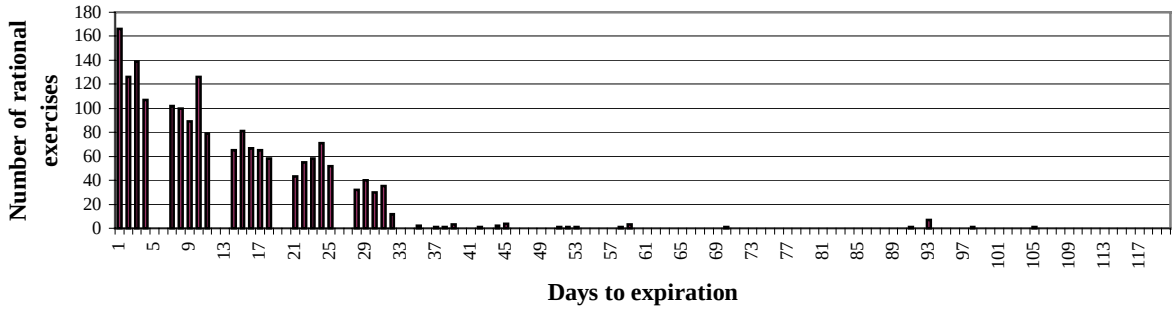
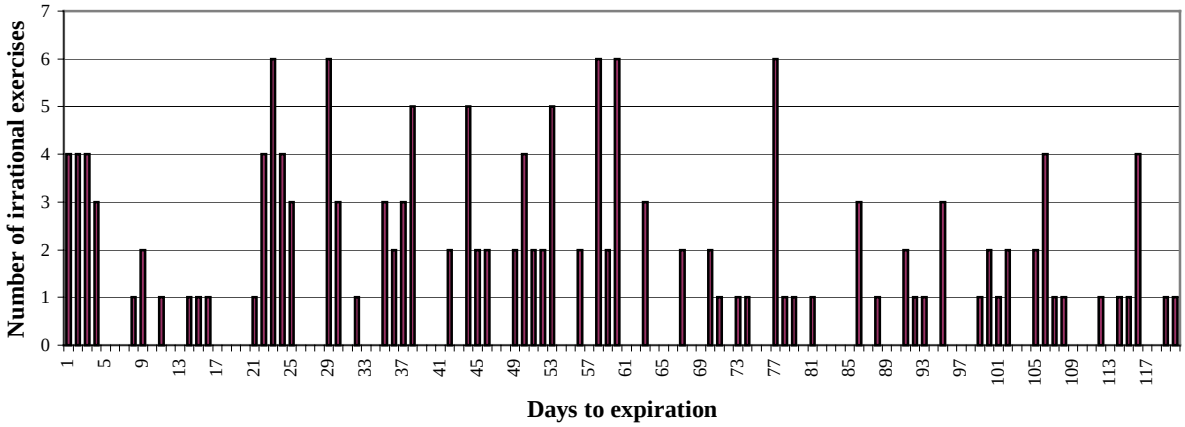


Figure 2. Rational early call exercises by number of calendar days left to expiration for various investor classes. This figure depicts the number of rational Chicago Board Options Exchange (CBOE) early call exercises as a function of the number of calendar days left to expiration by various investor classes over the period January 1996 through December 1999. Data on call exercises by the investor classes were obtained directly from the CBOE. Data on ex-dividend dates of underlying stocks and daily high stock prices are from the Center for Research in Security Prices. Data on daily low options prices are from Prophet Financial Systems. An option exercise is classified as rational if: (C1) The option is a call; (C2) The call is not at its expiration date; (C3) It is not the day before an ex-dividend date for the underlying stock; (C4) Data are available on the daily low transaction price for the call and daily high transaction price for the underlying stock; (C5) The daily trading volume for the call is at least ten contracts; (C6) The day's high price for the underlying stock exceeds the call's strike price; and (C7) The following inequality is satisfied: $C_t^{Low} - (S_t^{High} - K) \leq \$0.42$. Panels A, B, and C report the distributions of rational exercises for, respectively, discount customers, full service customers, and firm proprietary traders.

Panel A: Irrational Early Call Exercises by Discount Customers



Panel B: Irrational Early Call Exercises by Full Service Customers

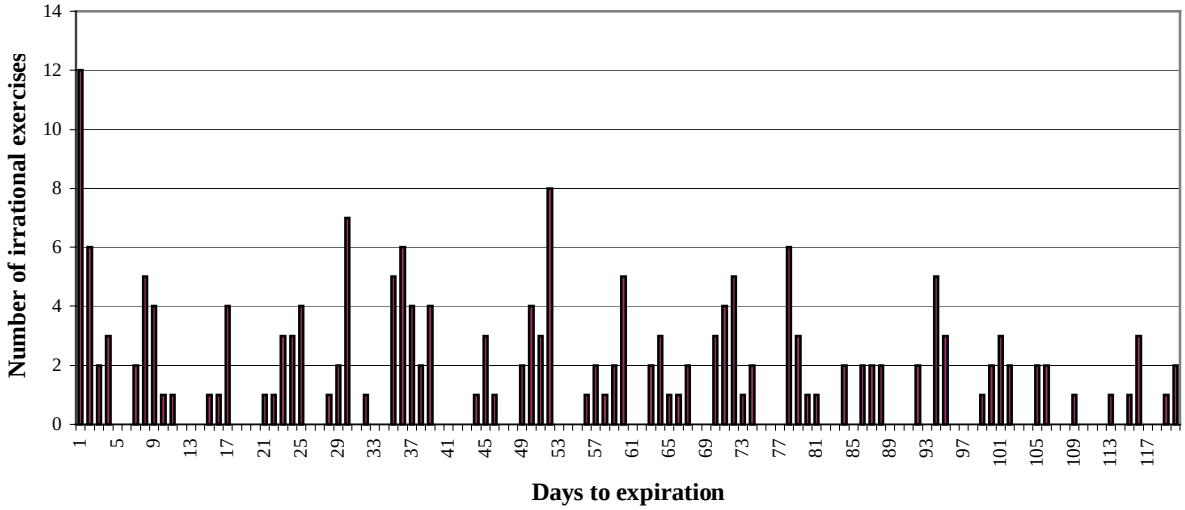


Figure 3. Irrational early call exercises by number of calendar days left to expiration for various investor classes. This figure depicts the number of irrational Chicago Board Options Exchange (CBOE) early call exercises as a function of the number of calendar days left to expiration by various investor classes over the period January 1996 through December 1999. Data on call exercises by the investor classes were obtained directly from the CBOE. Data on ex-dividend dates of underlying stocks and daily high stock prices are from the Center for Research in Security Prices. Data on daily low options prices are from Prophet Financial Systems. An option exercise is classified as irrational if: (C1) The option is a call; (C2) The call is not at its expiration date; (C3) It is not the day before an ex-dividend date for the underlying stock; (C4) Data are available on the daily low transaction price of the call and the daily high transaction price for the underlying stock; (C5) The daily trading volume for the call is at least ten contracts; (C6) The day's high price for the underlying stock exceeds the call's strike price; and (C7) The following inequality is satisfied: $C_t^{Low} - (S_t^{High} - K) > \$0.42$. Panels A and B report the distributions of irrational exercises for, respectively, discount customers and full service customers.