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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 exchange-traded options by different classes of investors over the 1996 to 1999 period. A large number of exercises are identified as clearly irrational without invoking any model of market equilibrium. 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. Rational and irrational exercise is triggered for discount and full-service customers by the underlying stock price attaining its highest level over the past year and by high returns on the underlying stock.

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 that 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 to 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).

Our first main finding is that 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-ser-

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vice customers both execute a significant number of irrational exercises. Firm proprietary traders, by contrast, carry out no early exercises that can be shown to be irrational. In addition to providing new information on the behavior of different types of option market investors, this finding contributes to an important debate over a large body of evidence that has emerged over recent decades that 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 little more than the very weak assumption that investors prefer more money to less.

Our second main result is that rational and irrational exercises are 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 rational and irrational exercise by discount and full-service customers even after controlling for the other event. This finding is broadly consistent with the prospect theory of Kahneman and Tversky (1979), because prospect theory maintains that investors become more risk averse after a gain or after exceeding a reference point and the act of exercising an option replaces a risky outcome with either a less risky outcome or a certain outcome.[2]

We do not provide evidence on the consequences of irrational exercise decisions for option prices. Generating such evidence would require choosing a model of market equilibrium. Since the central purpose of this paper is to study irrational investor behavior without specifying such a model, we leave the question of whether irrational exercise influences option prices for future investigation. It is worth noting, however, that the exercises which we identify as irrational would remain so under any model of market equilibrium that assumes investors prefer more money to less. Furthermore, any reasonable model of market equilibrium would make stronger assumptions and thereby classify more—possibly many more—exercises as irrational.

Our findings are most closely 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 to 1989 period. We extend his results by investigating the distribution of irrational exercise across investor classes and the events that trigger irrational exercise.[3] Heath, Huddart, and Lang find that the early exercise of executive stock options

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

[2] The new outcome is less risky if the share obtained upon exercise is held, and the new outcome is certain if the share obtained upon exercise is sold or used to cover a short position.

[3] 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.

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 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 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.

Our findings are also related to studies of the rationality of exercise decisions in other areas of finance. For example, there is evidence that people fail to exercise the option to refinance the mortgages on their homes when interest rates drop even though failing to refinance appears to be costly (Green and LaCour-Little (1999)). It is possible, however, that households that fail to refinance are not able to do so because of institutional barriers (e.g., collateral constraints, credit constraints, or income constraints). In addition, there may be hidden transaction costs (e.g., information gathering costs; Stanton (1995)) that prevent refinancing, or it may be the case that refinancing is actually suboptimal for households if they expect to move in the near future. There is also evidence that suggests that firms irrationally delay the exercise (i.e., the call) of convertible securities. Brennan and Schwartz (1977) and Ingersoll (1977a) show that in perfect capital markets, it is optimal for firms to call convertible securities as soon as the conversion value exceeds the call price. Ingersoll (1977b), however, finds that, on average, firms do not call convertible securities until their conversion value exceeds the call price by 43.9 percent. There are a number of possible explanations for Ingersoll's finding. Dunn and Eades (1989) argue that it makes sense for firms to delay exercising their option to call the convertible securities, because a substantial number of convertible holders suboptimally delay voluntary conversion. Asquith (1995), on the other hand, maintains that convertible bonds are not, in fact, called late once a reasonable safety premium (to ensure that the conversion value will exceed the call price after the normal 30-day call notice period) and several other factors are taken into account. Both the refinancing and convertible security examples are cases where agents choose not to exercise options. On the face of it, some of these decisions appear irrational, but since forgoing exercising has at least the potential to allow the agents to avoid costs, their rationality cannot be decisively determined. By contrast, the irrational behavior documented in this paper consists of cases where investors incur costs by irrationally choosing to exercise their equity options. Unlike the other cases, the evidence in this paper cannot be easily rationalized by appealing to timing, information, or other considerations.

The remainder of the paper is organized as follows. The first section describes the data. Section II develops the procedure that is used to classify early exercises as irrational. The third section presents results on the incidence of irrational

exercise behavior and analyzes its distribution across investor classes. The fourth section provides results on stock price patterns that trigger irrational exercise. Section V concludes.

I. Data

The main data for this paper were obtained from the CBOE. The data consist 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 cover 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. 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.[4]

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) the nearest 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 4,581 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 6,458 such exercises, and firm proprietary traders had 1,834.

II. Classification of Exercises as Irrational

We now turn to the task of identifying irrational option exercises under the weak assumption of nonsatiation—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

[4] The decimal points in the Prophet data were sometimes shifted. These shifts were identified and corrected.

Table I

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

This table presents descriptive statistics on CBOE calls, call exercises, and underlying stocks over the period January 1996 to 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 10 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 when there are 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.

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 10 contracts of the call trade on the date of exercise
Discount customer exercises	4,581	3,394
Full-service customer exercises	6,458	4,913
Firm proprietary trader exercises	1,834	1,798

Panel B: Call Option and Underlying Stock Descriptive Statistics

	25th percentile	Median	75th 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
Stock's high price minus closing price on exercise date ($)	0.1875	0.438	0.875	0.773	1.41

satisfied by as many exercises as possible, subject to the constraint that every identified exercise almost surely violates nonsatiation. Our criteria do not take into consideration two tax strategies that investors may have been trying to implement. We will, however, present evidence in the next section of the paper that it is unlikely that the exercises which we identify as irrational can be accounted for by these tax strategies.

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.

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 from 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.

This dominance argument does not cover two tax strategies under which an investor exercises an appreciated call and holds the share obtained in his portfolio. The first strategy, which is commonly referred to as "shorting against the box," defers a capital gain from one tax year to the next. An investor following this strategy would lock in a capital gain by simultaneously exercising the option and shorting the underlying stock. The long and short position in the underlying stock would then be held in the investor's portfolio until the next tax year, at which point the long position in the share would be used to close out the short position in the stock. These actions would defer capital gains tax to the next year, although they would not convert a capital gain from short-term to long-term. The second strategy would attempt to convert a short-term capital gain into a long-term capital gain by exercising and simply holding the share obtained for a year. (The tax laws do not allow the short-term gain to be converted into a long-term gain if the share obtained upon exercise is covered by shorting the stock or doing something substantially similar.) In the next section of the paper, we will provide evidence that the exercises that we classify as irrational are not executed as part of either of these tax strategies.

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:

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

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 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

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

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 $-Comm^{Sell\ Stock}(1-\tau_t)$, which can be smaller than our expression and therefore introduces, a bias toward classifying exercises as irrational.[5]

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:

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

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:

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

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-

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

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, to classify an exercise as irrational, we require inequality (4) to be satisfied.[6]

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 \$40.00 plus \$2.00 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, to be conservative, we will assume an upper bound on $Comm_t^{Sell\ Call}$ of \$0.42.[7]

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 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 forgoing 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 shares 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, to ensure that we do not misclassify any possibly rational exercises 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 call's 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

[6] 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*).

[7] 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 suggest that lesser upper bounds for these investors would not make much of a difference.

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

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

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 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.[8]

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

(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

[8] 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.

way criterion (C7) was developed, exercises which we categorize as rational are, in fact, irrational.

III. 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, ull-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 35), 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 rewrite inequality (5), which must be satisfied 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 to 1989 period. Our results, however, add to what is already known from Finucane, because (as noted in the previous section) his methodology is biased toward misclassifying exercises as irrational. Our results also extend those in Finucane 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 0 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. The E values are computed on a per-share basis, and the call contracts are for 100 shares each. As a result, the 0.892 number reported in Panel A as the median value of E for the irrational exercises of all investors aggregated together corresponds to wasting at least \$89.20 per call contract by exercising rather than selling. Taking account of the number of contracts associated with each irrational exercise, investors in aggregate wasted at least \$255,733.20 by irrationally exercising rather than selling. Because of the conservative way that we developed the criteria for classifying exercises as irrational, the actual amount of money wasted may be much larger both because the number of dollars wasted per irrational exercise is underestimated and because we fail to classify some exercises that violate nonsatiation as irrational.

Figures 1 and 2 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 2 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 1 for the rational exercises.

We now return to the two tax strategies discussed in the previous section. The Tax Reform Act of 1997 effectively outlawed shorting against the box as a way to defer capital gains tax from one year to the next. Consequently, if the exercises that we identify as irrational were actually part of a potentially rational shorting against the box strategy, we would expect to see them concentrated in the earlier part of our sample. In fact, 95 of the 195 exercises that we identify as irrational occurred in 1996–1997 and the other 100 occurred in 1998–1999. Hence, we do not believe that a shorting against the box tax deferral strategy provides a plausible

Table II

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

This table presents the distribution of $E \equiv C_t^{Low} - (S_t^{High} - K) - \$0.42$ for CBOE call option exercises over the period January 1996 to 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 10 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.

E	Obs.	Mean	Std.	Min.	1%	10%	25%	50%	75%	90%	99%	Max.
						Panel A: All Investors						
All	8,915	− 2.420	4.891	− 95.357	− 23.170	− 4.170	− 2.358	− 1.420	− 0.920	− 0.608	0.955	35.580
≤0	8,724	− 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	3,303	− 2.858	5.409	− 95.357	− 24.795	− 5.483	− 2.795	− 1.545	− 0.920	− 0.670	1.080	15.205
≤0	3,218	− 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	4,745	− 2.591	5.333	− 91.607	− 26.420	− 4.295	− 2.545	− 1.545	− 0.920	− 0.670	1.080	35.580
≤0	4,635	− 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	1,685	− 1.374	1.443	− 26.295	− 7.420	− 2.170	− 1.545	− 1.045	− 0.795	− 0.670	− 0.482	− 0.233
≤0	1,685	− 1.374	1.443	− 26.295	− 7.420	− 2.170	− 1.545	− 1.045	− 0.795	− 0.670	− 0.482	− 0.233
>0	0	—	—	—	—	—	—	—	—	—	—	—

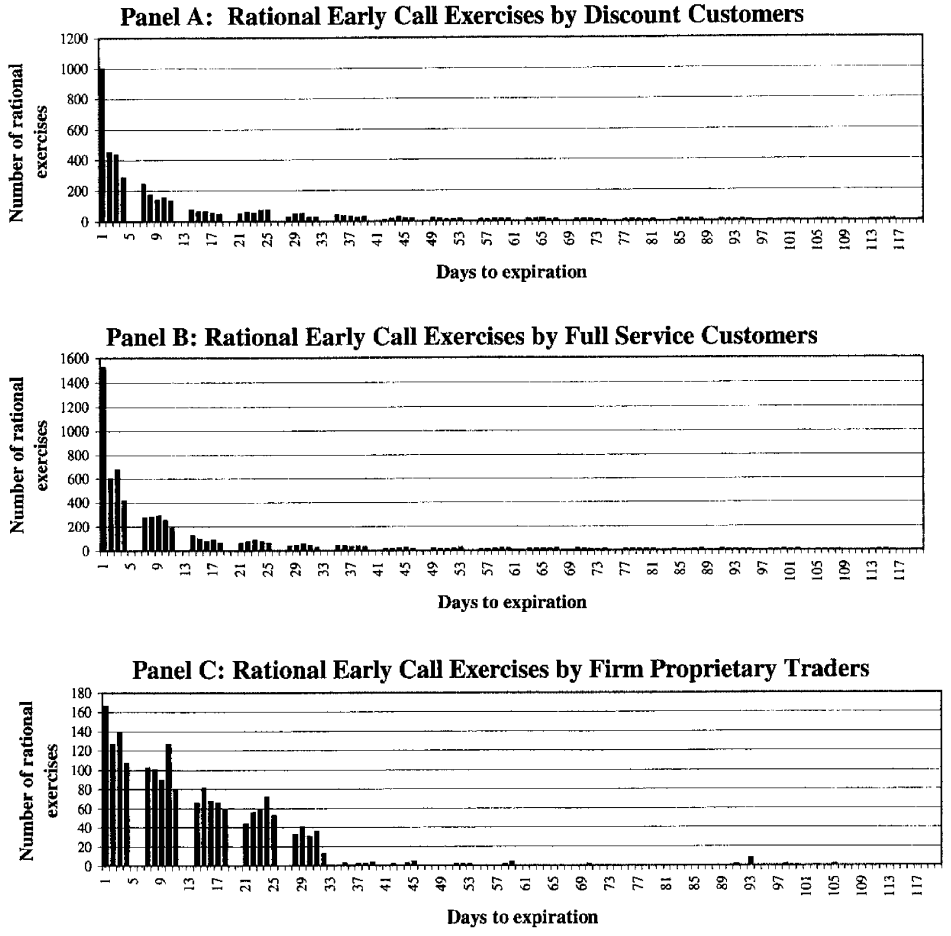

Figure 1. Rational early call exercises by the number of calendar days left to expiration for various investor classes. This figure depicts the number of rational Chicago Board Options Exchange (CBOE) early call exercises as a function of the number of calendar days left to expiration by various investor 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 10 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.

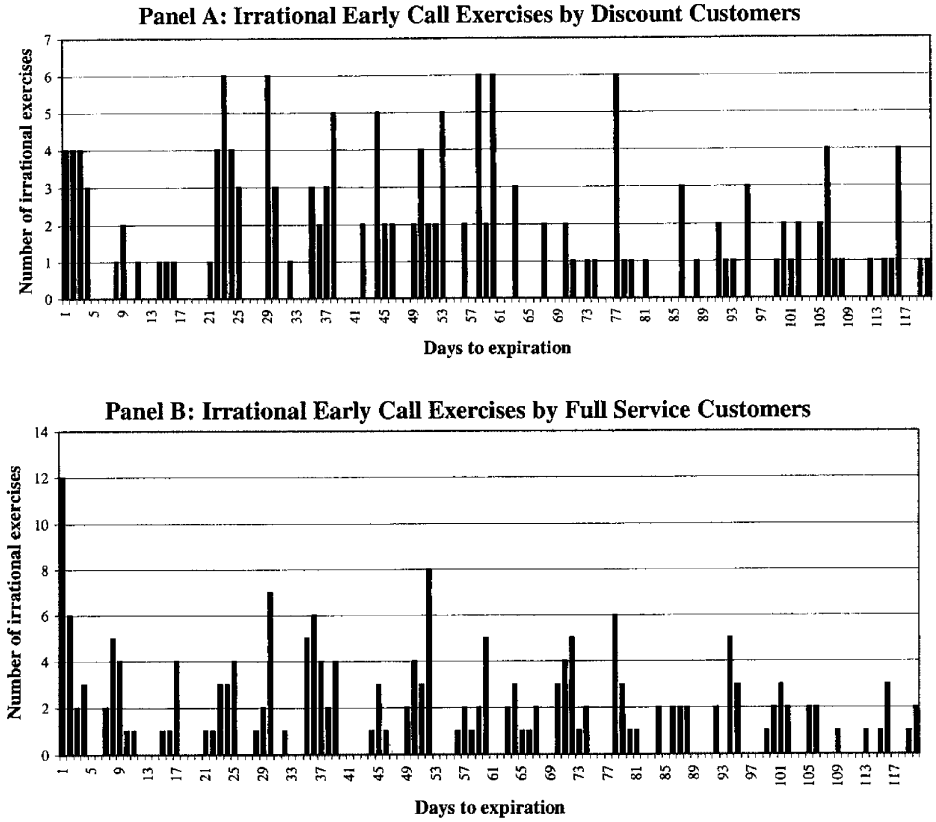

Figure 2. Irrational early call exercises by number of calendar days left to expiration for various investor classes. This figure depicts the number of irrational Chicago Board Options Exchange (CBOE) early call exercises as a function of the number of calendar days left to expiration by various investor 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 10 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.

alternative explanation for the exercises that are classified as irrational. The second tax strategy simply holds uncovered for at least a year a share obtained upon the exercise of an appreciated call in the hope of turning a short-term capital gain into a long-term capital gain. For this to be a plausible alternative explana-

tion for the exercises that we classify as irrational, it must at the time of exercise be unlikely that the call will end up out of the money at its expiration date. Otherwise, the investor should wait to exercise to avoid having purchased at the strike price a share of stock which has a value less than the strike price. It is evident from Figure 2 that the exercises that we classify as irrational often have a significant amount of time left before maturity when they are exercised. Furthermore, for the exercises that we identify as irrational, the median value of the stock price divided by the strike price at the time of exercise is 1.09. Consequently, there is a substantial risk at the time of early exercise that at the expiration date, the stock price will be less than the strike price. Hence, the second tax strategy is not a likely alternative explanation for the exercises we classify as irrational.

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 percent of potentially rational or irrational exercises are actually irrational. This percentage is 2.57 percent for discount customers, 2.32 percent for full-service customers, and 0 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 3,303 call-trade dates on which discount customers exercised and the 4,745 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 3,303 call-trade dates (without replacement) from the pool and treat them as the discount customer observations. We treat the other 4,745 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 1,000 times, and we count the number of times that the difference computed in step (2) exceeds the actual in-sample difference of 0.25 percent. In the test for the discount customers and the full-service custo-

Table III

Percentage of Potentially Rational or Irrational Chicago Board Options Exchange (CBOE) Call Exercises that Are Actually Irrational by Investor Type, January 1996 to 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 to 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 that 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 10 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 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 the 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.

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	8,915	3,303	4,745	1,685
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 of 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

mers, the difference was greater than 0.25 percent 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 difference 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. It should be noted, however, that a full-service broker would typically receive a greater commission when a customer exercises his call and sells the stock than when he simply sells the call. 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. 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 percent of their irrational exercise opportunities and full-service customers exercise on 0.041 percent 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 percent of their opportunities to exercise rationally, while full-service customers act on 1.66 percent of such opportunities, and firm proprietary traders act on 2.69 percent 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.

Table IV

Percentage of Irrational and Rational Chicago Board Options Exchange (CBOE) Exercise Opportunities that Result in Exercise by Investor Type, January 1996 to 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 to 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 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	3,218	110	4,635	0	1,685
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

IV. Yearly High Prices, 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 attaining its yearly high price 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 is at a 52-week high or contains 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:

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

The subscript i denotes either all investors, discount customers, or full-service customers.[9]

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.

$$YearlyHigh_{jt} = \begin{cases} 1 & \text{if closing price of stock } j \text{ on trade date } t \text{ is a 52-week high} \\ 0 & \text{otherwise.} \end{cases} \tag{9}$$

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

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.

$$RetWeek1_{jt} = \text{Cumulative return on stock } j \text{ for trade dates } t - 5 \text{ through } t - 1 \tag{10}$$

$$RetWeek2_{jt} = \text{Cumulative return on stock } j \text{ for trade dates } t - 10 \text{ through } t - 6 \tag{11}$$

$$RetWeek3_{jt} = \text{Cumulative return on stock } j \text{ for trade dates } t - 15 \text{ through } t - 11 \tag{12}$$

$$RetWeek4_{jt} = \text{Cumulative return on stock } j \text{ for trade dates } t - 20 \text{ through } t - 16 \tag{13}$$

$$RetMonth2_{jt} = \text{Cumulative return on stock } j \text{ for trade dates } t - 42 \text{ through } t - 21 \tag{14}$$

$$RetMonth3To6_{jt} = \text{Cumulative return on stock } j \text{ for trade dates } t - 126 \text{ through } t - 43. \tag{15}$$

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 options held by investor class i on trade date t that are written on stock j and which satisfy (C1)–(C7):

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

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:

$$\begin{aligned} Exercise_{ijt}^{Irrational} =& \beta_0 + \beta_1 YearlyHigh_{jt} + \beta_2 RetWeek1_{jt} + \beta_3 RetWeek2_{jt} \\ &+ \beta_4 RetWeek3_{jt} + \beta_5 RetWeek4_{jt} + \beta_6 RetMonth2_{jt} \\ &+ \beta_7 RetMonth3To6_{jt} + \beta_8 CashFlowLoss_{ijt} + \varepsilon_t. \end{aligned} \tag{17}$$

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

Table V

Descriptive Statistics for Logit Regression Variables, January 1996 to December 1999

This table reports descriptive statistics for variables constructed over the time period January 1996 to December 1999, which will be used in logit regressions. The investor 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:
$C_t^{Low} - (S_t^{High} - K) > \$0.42 / C_t^{Low} - (S_t^{High} - K) \leq \$0.42$.
That is,

$$Exercise_{ijt}^{Irrational/Rational} = \begin{cases} 1 & \text{if investor class } i \text{ exercises a (C1) – (C6) call on stock } j \text{ on trade date } t \\ & \text{for which } C^{Low} - (S^{High} - K) > 0.42 / C^{Low} - (S^{High} - K) \leq 0.42 \\ 0 & \text{if investor } i \text{ has open interest in but no exercises of these calls.} \end{cases}$$

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.

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

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.

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

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 options held by investor class i on trade date t that are written on stock j and which satisfy (C1)–(C6):

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

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 kth 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 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	Std. dev.	25th percentile	Median	75th percentile
*RetWeek*1	0.014	0.086	– 0.030	0.011	0.054
*RetWeek*2	0.009	0.084	– 0.032	0.007	0.048
*RetWeek*3	0.009	0.083	– 0.032	0.007	0.047
*RetWeek*4	0.008	0.083	– 0.033	0.006	0.046
*RetMonth*2	0.031	0.159	– 0.052	0.029	0.110
*RetMonth*3*To*6	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
$Exercise_{ijt}^{Rational}$, i = Discount Customers	118,412	85	0.07
$Exercise_{ijt}^{Irrational}$, i = Full-Service Customers	126,746	110	0.08
$Exercise_{ijt}^{Rational}$, i = Firm Proprietary Traders	34,519	0	0.00
YearlyHigh	119,364	10,807	9.05

Table V—*continued*

Panel B: Rational Exercise Opportunities

Continuous Variables

	Mean	Std. dev.	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	2,754	2.43
$Exercise_{ijt}^{Rational}$, i = Full-Service Customers	123,812	3,815	3.08
$Exercise_{ijt}^{Rational}$, i = Firm Proprietary Traders	38,466	1,558	4.05
YearlyHigh	119,752	11,888	9.92

Table VI

Logit Regression of Irrational Exercise Opportunities on Explanatory Variables, January 1996 to December 1999

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

This table reports the results of logit regressions over the January 1996 to 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 10 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,

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

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.

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

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 $t-43$.

Table VI—*continued*

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 options held by investor class i on trade date t that are written on stock j and which satisfy (C1)–(C6):

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

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.

	All traders	Discount customers	Full-service customers
Constant	− 6.865	− 7.613	− 7.326
	(50.77)**	(36.22)**	(41.82)**
YearlyHigh	0.683	0.493	0.921
	(3.60)**	(2.70)*	(3.85)**
*RetWeek*1	2.358	3.849	1.775
	(3.19)**	(3.77)**	(1.76)
*RetWeek*2	2.334	2.903	1.823
	(3.16)**	(2.69)**	(1.85)
*RetWeek*3	2.675	2.904	2.404
	(3.77)**	(2.85)**	(2.52)*
*RetWeek*4	2.149	1.674	2.377
	(3.01)**	(1.71)	(2.55)*
*RetMonth*2	1.914	2.047	1.701
	(5.09)**	(3.62)**	(3.44)**
*RetMonth*3*To*6	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.
*is significant at the five percent level
**is significant at the one percent level

full-service customers separately. The estimate on the yearly high price 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. In addition, it should be emphasized that a stock-trade date is only included in the regressions if the relevant investor class has open interest on calls of the underlying stock that are in the money. For this reason, a significantly positive coefficient on the yearly high price variable indicates that when the underlying stock reaches a yearly high, investors have a greater propensity to exercise their in-the-money calls.[10]

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.

We next investigate whether the events that trigger irrational option exercise also trigger the option exercises that we classify as rational. 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:

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

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 yearly high price variable and all of the past returns variables that are positive. Now all of these coefficient estimates are significant at

[10] We also reran the regressions in Table VI and in the tables below with an additional independent variable that controls for the extent to which calls are in the money. The addition of this control variable does not alter any of the main features of the results.

Table VII

Logit Regression of Rational Exercise Opportunities on Explanatory Variables, January 1996 to December 1999

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

This table reports the results of logit regressions over the January 1996 to 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 10 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,

$$Exercise_{ijt}^{Rational} = \begin{cases} 1 & \text{if investor class } i \text{ exercises a (C1) – (C6) and (C7′) call on stock } j \text{ on trade date } t \\ 0 & \text{if investor class } i \text{ has open interest in but no exercises of these calls.} \end{cases}$$

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.

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

Stock splits and stock dividends are taken into account when computing this variable. The next set of independent variables is 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 options held by investor class i on trade date t that are written on stock j and which satisfy (C1)–(C6):

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

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.

	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)**
YearlyHigh	0.373	0.433	0.437	− 0.036
	(9.07)**	(7.42)**	(8.39)**	(0.31)
*RetWeek*1	2.670	3.298	3.225	− 4.298
	(18.31)**	(15.79)**	(17.42)**	(10.61)**
*RetWeek*2	2.117	2.930	2.384	− 2.438
	(14.03)**	(13.60)**	(12.27)**	(5.74)**
*RetWeek*3	1.420	1.802	1.756	− 1.889
	(9.43)**	(8.22)**	(9.08)**	(4.52)**
*RetWeek*4	1.011	1.378	1.301	− 1.621
	(6.73)**	(6.34)**	(6.75)**	(3.89)**
*RetMonth*2	0.759	0.960	0.900	− 0.997
	(9.70)**	(8.36)**	(8.89)**	(4.61)**
*RetMonth*3*To*6	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.
*is significant at the five percent level
**is significant at the one percent level.

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

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 yearly high price 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 last issue that we investigate is the relationship between alternative definitions of the yearly high price variable and irrational exercise behavior. Until now, the yearly high price variable has indicated whether the current price of the underlying stock is higher than it has been over the past 52 weeks. Table VIII reports the results of rerunning the irrational exercise regressions from Table VI when this variable is set to one when the current price of the underlying stock is either 75 percent, 50 percent, or 25 percent of the highest closing price over the previous 52 weeks. To conserve space, only the coefficients on the yearly high price 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 yearly high price variable. The second row reports this coefficient when the yearly high price 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 yearly high price variable 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 level of the underlying asset that triggers irrational exercise by the investors.

V. 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

Table VIII

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

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

This table reports the results of logit regressions over the January 1996 to 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 10 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,

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

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

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

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

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

Table VIII—*continued*

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

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.

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

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 options held by investor class i on trade date t that are written on stock j and which satisfy (C1)–(C6):

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

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.

YearlyHigh dummy = 1 if	All traders	Discount customers	Full-service customers
(Closing price)/(52-week high) ≥ 1	0.683	0.493	0.921
	(3.60)**	(2.70)*	(3.85)**
0.75 ≤ (Closing price)/(52-week high) < 1	0.222	0.055	0.303
	(1.43)	(0.24)	(1.49)
0.50 ≤ (Closing price)/(52-week high) < 0.75	− 0.827	− 0.353	− 1.350
	(3.30)**	(1.07)	(3.43)**
0.25 ≤ (Closing price)/(52-week high) < 0.50	− 1.209	− 1.062	− 1.396
	(2.35)*	(1.45)	(1.93)

Absolute value of z-statistics in parentheses.
*significant at the five percent level
**significant at the one percent level

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 rational and 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 rational and irrational exercise even after controlling for the other event. This finding is broadly consistent with prospect theory, since exercising an option replaces a risky outcome with either a less risky outcome if the share obtained upon exercise is held or a certain outcome if the share obtained is sold or used to cover a short position.

We do not provide evidence on the consequences of irrational exercise behavior for option prices. Generating such evidence would require choosing a model of market equilibrium. Since the purpose of this paper is to study irrational investor behavior without choosing such a model, we leave the interesting question of whether irrational exercise influences option prices for future research.

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