Put – Call Parity Violations around Earnings Announcements

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This study extends the previous work on put-call parity violations and informed trading in the options market by examining the impact of earnings announcements on put-call parity boundary violations of American style options on non-dividend paying stocks. Consistent with informed investors trading first in the options market, the results show that there is a significant increase in put-call parity boundary violations around earnings announcements. In addition, the increase in violations is higher for firms that are difficult to value such as growth firms. These violations predict reversals in stock returns, which indicate that investors in the options market are more informed than stock market investors. The results remain significant even after taking into account the effects of transaction costs and illiquidity.

JEL classification: G02; G10; G14
Keywords: Put – Call Parity, Earnings Announcements

1. Introduction

Put-call parity is one of the basic tenets of option pricing theory. It shows the relationship that must hold between the underlying stock price and the price of the put and call options with the same strike price and expiration. Generally, trading strategies and option pricing models are developed based on the assumption that put-call parity relationships are not violated. However, given the size of the markets for options and stocks, whether the market data supports the existence of put-call parity relationship always is an issue worthy of investigation. If this pricing relationship is violated significantly in practice, it could have far-reaching implications. For example, if the violations are due to inefficiencies in the market, such inefficiencies could be exploited by market participants to make arbitrage profits. On the other hand, if the observed violations are due to shortcomings in the option pricing models, then it opens up the possibility of making improvements in these models. In this paper, I document that put-call parity boundary violations increase significantly on the earnings announcement day.

Earnings announcements are important sources of information released by firms. Researchers have found that not only do large changes in stock prices occur frequently around earnings announcements, but stock prices also deviate from their fundamental values (Barberis, Shleifer and Vishny, 1998). One would expect the mispricing in the stock market to carry over to the options market, since the price of the underlying stock is an input for the traditional option pricing models. However, Black (1975) suggests that informed traders are more likely to trade in the options market in order to take advantage of lower transaction costs, greater financial leverage and fewer short sale constraints.[1] If the options market consists mostly of informed investors, then the stock price implied from the options market will on average be closer to the intrinsic value compared to the prices in the stock market. This can cause the stock price and the implied stock price from the options market to diverge. If there are restrictions on arbitrage, the mispricing will not be corrected immediately, resulting in put-call parity violations.

In this paper, using a sample of more than 36,000 firm-quarters, I investigate whether earnings

[1] For example, if an investor is prohibited from shorting the stock on a down tick then he could instead create a short position using options, and if margin requirements prohibit the investor from obtaining the desired amount of leverage, then the investor can obtain the same leverage by buying options.

announcements systematically affect put-call parity boundary conditions for American style options on non-dividend paying stocks. Specifically, I consider both the upper bound and lower bound violations around earnings announcements. An upper bound violation occurs when the stock price is greater than the price implied from the options market, and a lower bound violation occurs when the stock price is less than the price implied from the options market.

I find that the percentages of both upper and lower bound violations increase significantly on the earnings announcement day. The results remain significant even after taking into account the effects of transaction costs (bid-ask spread) and illiquidity. Consistent with informed investors trading first in the options market, upper bound violations predict negative stock returns, while lower bound violations predict positive stock returns.

I further analyze the put-call parity violations around earnings announcements by performing a cross-sectional analysis across firms. Firms with more growth opportunities should attract more information-motivated trading because of the greater uncertainty in their valuation. Using the book-to-market ratio as a proxy for expected future growth, I find that firms with low book-to-market ratio (growth firms) have a greater increase in put-call parity violations on the earnings announcement day. Firms with high option liquidity should also have a higher percentage of information-motivated trading because high liquidity makes it easier for informed traders to hide their identity. Using market capitalization as a proxy for options market liquidity, I find that large firms have a greater increase in the put-call parity violations on the earnings announcement day.

To the best of my knowledge, this paper is the first to examine the put-call parity boundary violations around earnings announcements, and in doing so, extends the previous work on put-call parity violations and informed trading in the options market. The analysis in the paper is model independent, as it does not impose any assumption on the probability distribution of the underlying stock, as well as other assumptions such as continuous trading. The results of my paper suggest that, in the presence of market imperfections, the release of new information does have a strong influence on the pricing of stock options. It throws more light on where informed investors trade and how investors process earnings information. Furthermore, the evidence indicates that the put-call parity violations can be used to predict future stock price movements around earnings announcements.

The remainder of this paper is organized as follows: Section 2 presents the literature review. Section 3 presents the hypothesis. Section 4 details the methodology. Section 5 explains the data. Section 6 discusses the empirical results, and section 7 summarizes and concludes the paper.

2. Literature Review

2.1. Put-call Parity Violations

When there are no dividend payments and no arbitrage restrictions, such as short-sale constraints, the basic put-call parity condition formalized by Stoll (1969) for European style options is as follows:

$$S = PV(X) + C - P \tag{1}$$

where S is the stock price, $PV(X)$ is the present value of the strike price, and C and P are the call and put prices, respectively, on options with strike price X and same maturity. For American style options, Merton (1973) shows that equation (1) does not hold, as put options are more valuable due to the possibility of early exercise. However, the following put-call parity boundary condition holds for American style options on non-dividend paying stocks.

$$PV(X) + C - P \leq S \leq X + C - P. \tag{2}$$

Researchers have tested the basic put-call parity condition (equation (1)) on individual stock options. Gould and Galai (1974) and Klemkosky and Resnick (1979) and Bhatacharya (1983) consider a small sample of stock options traded on the Chicago Board of Options Exchange, while Nisbet (1992) examines a larger sample of 55 stock options traded on the London Options Market. These authors find that the put-call parity violations cannot be exploited if transaction costs are

taken into consideration. One major drawback of these studies is that the individual stock options are of American style and equation (2) instead of equation (1) should be tested. To circumvent the problem, Kamara and Miller (1995) test the basic put-call parity condition (equation (1)) on the S&P 500 index options that are of European style. They show that the put-call parity violations for the index options are less frequent and smaller in magnitude than those for the American style options in previous studies.

Some recent studies focus on the causes of put-call parity violations. Lamont and Thaler (2003) examine a small sample of three stocks that have gone through an equity carve-out and the parent sells for less than its ownership stake in the carve-out. They find extensive violations of put-call parity, and that these violations are consistent with the high costs of short selling these stocks. Using a large sample of non-dividend paying equity options, Ofek, Richardson, and Whitelaw (2004) also show that the put-call parity violations are strongly related to the cost and difficulty of short selling. To adjust for the early exercise premium of American style put options, they examine the violations of the following put-call parity condition:

$$S = PV(X) + C - P + EEP, \tag{3}$$

where *EEP* refers to the early exercise premium of American style put options. One drawback of their approach is that the early exercise premium has to be estimated, which makes equation (3) no longer an empirical no-arbitrage condition.

2.2. Informed trading in the option market

To explain why the put-call parity violations occur in the first place, Ofek, Richardson, and Whitelaw (2004) document evidence consistent with a behavioral story, where the stock and option markets are segmented and the stock market investors are overly optimistic. They show that stocks with relatively expensive puts subsequently earn negative abnormal returns and conclude that the put-call parity violations (equation (3)) are a result of mispricing in the stock market and informed trading in the options market. Cremers and Weinbaum (2010) also find evidence of informed trading in the options market. They use the implied volatility spread between matched put and call option pairs to measure deviations from put-call parity and find it to predict stock returns.

Kumar, Sarin, and Shastri (1998) and Cao (1999) argue that there is greater benefit to acquire private information and being informed if options are traded on the underlying asset. Easley, O'Hara, and Srinivas (1998) and Pan and Poteshman (2006) find that the option trading volume contains information about future stock prices. Cao and Ou-Yang (2009) find that investors are more likely to trade in options when there is a difference in opinion about public information.

There is also evidence that informed trading takes place in the options market before the announcements of important firm-specific news. Patell and Wolfson (1979) and Patell and Wolfson (1981) examine the level of implied volatility around earnings announcements, and conclude that the options market leads the stock market. Amin and Lee (1997) examine the option market activity around earnings announcements and find that investors use private information to trade in the options market. Jennings and Starks (1986) and Ho (1993) find that stocks that have options traded adjust to earnings announcement surprises faster than non-optionable stocks. Similar to Cremers and Weinbaum (2010), Atilgan (2010) also shows that the implied volatility spread can predict stock returns specifically around earnings announcements. A few papers have also documented evidence of informed trading in the options market around merger announcements (see Cao, Chen, and Griffin, 2005, and Jayaraman, Frye, and Sabherwal, 2001).

As Black (1975) suggests, there is empirical evidence that informed trading takes place in the options market and that options increase the informational efficiency of the underlying asset. Further, Easley, O'Hara, and Srinivas (1998) develop an information-based trading model, where the existence of informed traders can lead to put-call parity violations. They show that option implied stock prices would deviate from the stock price in the direction of the informed investors' private information. In

the presence of limits to arbitrage, the private information will not be incorporated into the underlying stock price immediately, therefore resulting in put-call parity violations.

3. Hypothesis

It has been well documented that stock prices tend to drift following quarterly earnings announcements (see Ball and Brown, 1968; Bernard and Thomas, 1989; Chan, Jegadeesh, and Lakonishok, 1996; Sadka, 2006; Garfinkel and Sokobin, 2006; and Hong and Stein, 2007). Researchers have attributed the post earnings announcement drift to investors' underreaction to news (see Barberis, Shleifer, and Vishny, 1998, and Lafond, Olsson, and Schipper, 2007). The general conclusion in this literature is that the stock market does not fully process information in earnings announcements.

In contrast, because the options market consists of more informed investors who can better interpret the earnings surprise and/or have private information about the fundamental value of the firm, the mispricing in the stock market around earnings announcements may not carry over to the option market. Numerous papers in the literature show that investors have greater incentive to obtain private information around earnings announcements (Kim and Verrecchia, 1997; Holthausen and Verrecchia, 1990; and Barron, Harris, and Stanford, 2005). Investors with private information tend to trade on the earnings announcement day because the new information contained in earnings announcements enables them to capitalize on their private information to draw new inferences regarding the firm value. Moreover, even for the public information in earnings announcements such as future firm profitability and growth potential, some investors are better than others in interpreting the information (see Kim and Verrecchia, 1995).

If informed investors trade first in the options market around earnings announcements, then the stock price will drift away from its implied price obtained from the option market and if there are limits to arbitrage, the mispricing will not be corrected immediately. In practice, there are several factors such as transaction costs, margin requirements, taxes, and short sale constraints that limit investors' ability to undertake riskless arbitrage transactions (see Ng, Rusticus and Verdi, 2008, and Brav, Heaton and Li, 2010). My first hypothesis is that there are more put-call parity boundary violations on the earnings announcement day due to the divergence of the observed and implied stock prices.

Second, observing put-call parity violations, arbitragers will take advantage of the mispricing and their trading activities will force the two stock prices to eventually converge once all the private information is incorporated in the underlying stock price. Therefore, the put-call parity violations on the earnings announcement day can predict future stock returns. Specifically, I hypothesize that upper bound violations predict negative stock returns and that lower bound violations predict positive stock returns.

Third, if put-call parity violations are caused by segmentation of the stock and option markets with more informed traders in the options market, one would expect more put-call parity violations for firms with more asymmetric information and therefore more difficult to value. Consistent with this line of thinking, Ofek, Richardson, and Whitelaw (2004) show that put-call parity violations are greater when the potential level of mispricing in the underlying stocks is higher. In this paper, I use the book-to-market ratio to proxy the level of information asymmetry, as firms with more growth opportunities (low book-to-market) are associated with greater uncertainty in valuation (see Lakonishok, Shleifer, and Vishny, 1994, and Skinner and Sloan, 2002). Growth firms are also more likely to attract information motivated trading because they offer potentially large returns on capital invested in information-generating activities. Skinner and Sloan (2002) also find that the stock price reaction to earnings surprise is stronger for growth (low book-to-market) stocks as compared to value (high book-to-market) stocks. Therefore, I hypothesize that the increase in put-call parity boundary violations on the earnings announcement day are greater for growth firms than for value firms.

Finally, Easley, O'Hara, and Srinivas (1998) build and test a model where informed investors are more likely to trade in the option market when liquidity is high because it allows informed investors to

hide their transactions. Using firm size (market equity) as a proxy of liquidity in this paper, I hypothesize that the increase in put-call parity boundary violations on the announcement day are greater for big firms than for small firms.

4. Methodology

In this paper, I examine the impact of quarterly earnings announcements on the following two put-call parity boundary conditions of American style options on non-dividend paying stocks (see Amin, Coval, and Seyhun (2004) for similar conditions):[2]

$$Upper\ Bound \ \rightarrow \ S \leq X + C - P \tag{4}$$

$$Lower\ Bound \ \rightarrow \ S \geq PV(X) + C - P \tag{5}$$

These put-call parity boundary conditions are model independent and based on the concept of arbitrage. If the upper bound condition is violated, then one can make arbitrage profits by short selling the stock, selling the put option, buying the call option and lending the exercise price. If the lower bound condition is violated, then one can make arbitrage profits by buying the stock, borrowing at the present value of the exercise price, buying the put option, and selling the call option.

It is important to incorporate transaction costs in equation (4) and equation (5), since previous research has shown that the put-call parity violations disappear once transaction costs are included in the analysis. In calculating the upper bound and the lower bound conditions, I assume that the stock purchase is done at the last transaction price (buy or sell) and that options are bought and sold at the ask and bid prices. The upper bound (UB) and lower bound (LB) values adjusted for transaction costs are defined as follows:

$$UB = \begin{cases} 0 & if \quad S \leq X + C_{ask} - P_{bid} \\ S - X - C_{ask} + P_{bid} & if \quad S > X + C_{ask} - P_{bid} \end{cases} \tag{6}$$

$$LB = \begin{cases} 0 & if \quad S \geq PV(X) + C_{bid} - P_{ask} \\ PV(X) + C_{bid} - P_{ask} - S & if \quad S < PV(X) + C_{bid} - P_{ask} \end{cases} \tag{7}$$

An upper bound violation is said to occur when the upper bound value in equation (6) is positive. Similarly, a lower bound violation is said to occur when the lower bound value in equation (7) is positive. The upper bound and lower bound values are calculated for each option pair and are rounded off to the fourth decimal place in order to prevent introduction of numerical noise within the results.[3]

A stock can have numerous pairs of put and call options with different combinations of strike price and maturity date, therefore I calculate the percentage of upper bound and lower bound violations and the average magnitude of upper bound and lower bound violations for each stock on each day. The percentage of upper bound and lower bound violations is calculated using the number of option pairs, call and put option open interest and call and put option volume. When calculating the average magnitude of upper bound and lower bound violations, I weight the violations using the number of options and call and put option open interest.

5. Data

The options data is obtained from OptionMetrics for the sample period January 1996 through

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[2] I focus only on American style options since all the exchange-traded stock options are American style options. Similar to Ofek, Richardson, and Whitelaw (2004), I also eliminate all dividend-paying stocks. Thus, American style call options can be treated as European style call options and no divided adjustments are necessary to evaluate the boundary conditions.

[3] In order to calculate the lower bound value, I need a zero-coupon continuously compounded interest rate whose maturity matches the expiration dates on the options. This interest rate is obtained from OptionMetrics. The zero-curve provided by Option-Metrics is derived from LIBOR rates and settlement prices of CME Eurodollar futures. For a given option, the appropriate interest rate input corresponds to the zero-coupon rate that has a maturity equal to the option's expiration, and is obtained by linearly interpolating between the two closest zero-coupon rates on the zero curve.

June 2005. OptionMetrics provides end-of-day bid and ask quotes, open-interest and volume data on every call and put option on an individual stock traded on a U.S. exchange. The bid-ask prices in OptionMetrics are the highest closing bid price and the lowest closing ask price across all exchanges on which the option trades. Option-Metrics also provides data on the underlying stock price and dividends. Additional data such as the quarterly earnings announcement dates, book values and market values of the firm are obtained from Compustat and the size-decile adjusted returns for the firm are obtained from the CRSP database.

Table 1
Sample Description

	Trading Day [-22,+20]		Trading Day [-10]		Trading Day [0]		Trading Day [+10]	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Panel A: Full Sample								
Number of option pairs per firm	17.62	14.00	17.54	14.00	17.75	14.00	17.77	14.00
Call open interest per firm	8550.05	1372.00	8429.41	1328.00	8669.52	1393.00	8779.45	1441.00
Put open interest per firm	5364.85	573.00	5282.44	553.00	5361.64	571.00	5511.66	599.00
Call volume per firm	480.05	32.00	460.55	30.00	984.86	81.00	429.16	29.00
Put volume per firm	248.14	4.00	243.90	2.00	547.42	20.00	219.64	2.00
Avg. call price bid-ask spread per firm	0.30	0.24	0.30	0.24	0.30	0.23	0.31	0.25
Avg. put price bid-ask spread per firm	0.26	0.21	0.26	0.21	0.25	0.20	0.26	0.21
Panel B: Sample of options with UB violations								
Number of option pairs per firm	0.23	0.00	0.25	0.00	0.37	0.00	0.21	0.00
Call open interest per firm	2650.85	308.00	2341.77	300.00	3911.37	357.00	2546.87	352.00
Put open interest per firm	2293.45	130.00	2025.62	130.50	2762.53	169.00	2265.48	124.00
Call volume per firm	260.30	10.00	245.52	10.00	782.87	37.00	197.25	10.00
Put volume per firm	182.91	0.00	167.16	0.00	612.63	20.00	130.81	0.00
Avg. call price bid-ask spread per firm	0.20	0.11	0.21	0.11	0.19	0.10	0.20	0.12
Avg. put price bid-ask spread per firm	0.11	0.09	0.12	0.10	0.10	0.09	0.12	0.10
Panel C: Sample of options with LB violations								
Number of option pairs per firm	0.29	0.00	0.31	0.00	0.46	0.00	0.27	0.00
Call open interest per firm	1375.98	216.00	1467.85	219.00	2058.19	259.00	1554.66	216.00
Put open interest per firm	918.09	75.00	942.74	70.50	1451.41	80.00	1087.23	80.00
Call volume per firm	167.71	4.00	155.44	4.00	486.16	20.00	148.50	1.00
Put volume per firm	83.44	0.00	85.55	0.00	261.01	0.00	84.50	0.00
Avg. call price bid-ask spread per firm	0.10	0.09	0.10	0.09	0.10	0.08	0.10	0.09
Avg. put price bid-ask spread per firm	0.19	0.13	0.20	0.13	0.18	0.12	0.20	0.13

I begin with the options data for 22 trading days before and after the quarterly earnings announcement day and then apply a set of filters to the data. I first eliminate put and call options on all dividend-paying stocks. For the analysis and results shown in this paper, a dividend paying stock

is defined as one that reports a dividend payment between January 1996 and June 2005. OptionMetrics also provides implied volatility data, which is calculated from the Cox-Ross-Rubenstien binomial tree model. There are some cases where the implied volatility data is missing.[4] In order to improve the quality of the data, I eliminate all the options that do not have implied volatility data. I also eliminate call and put options that do not have a corresponding put or call option with the same maturity and exercise price, since both the put and call option prices are required to calculate the upper bound and lower bound values. For some option pairs both the upper bound and lower bound values are violated. This occurs because bid and ask prices are used to calculate the upper bound and lower bound values. Such option pairs are not considered in the current analysis.

Table 1, Panel A describes the entire sample of option pairs used in this paper. The sample consists of 28,225,607 option pairs over 22 trading days around earnings announcements. There are 36,564 firm-quarters and 2,716 different firms in the sample. Table 1 also provides a description of the sample on the day of the earnings announcement and on the 10th day before and after the earnings announcement day. It is interesting to note that call and put option trading volume double on the earnings announcement day. On any given day, the open interest and volume of call options are higher than the open interest and volume of put options. This shows that call options are traded more compared to put options.

Table 1, Panels B and C provide a description of the sample of options with upper bound and lower bound violations. For both the upper bound and lower bound violation, the number of options per firm with violations increases on the day of the announcement. At the same time, put and call open-interest and volume are also higher on the announcement day. Furthermore, the option bid-ask spread (for both call and put) is much lower for the options with violations than it is for the full-sample of options. This shows that the violations are not due to illiquid options.

6. Results

6.1. Put-call parity violations around earnings announcements

In this section, I examine the percentage and magnitude of upper bound and lower bound put-call parity violations around earnings announcements. Figure I shows the percentage of upper bound and lower bound violations for 22 trading days before and after the earnings announcement day. The percentage of violations is value weighted using the number of options pairs per stock on each trading day. Consistent with the first hypothesis, both the upper bound and lower bound violations peak on the earnings announcement day. On non-announcement days, the average percentage of upper bound violations is around 1.3%, and the average percentage of lower bound violations is around 1.7%. On the earnings announcement day, both the upper bound and lower bound violations increase to 2.1% and 2.6% respectively.

A stock can have numerous pairs of put and call options, but the open interest and trading volume on the options can be low and a number of the options can even have zero trading volume. Therefore using the number of options may not be a good method of weighting the violations. In order to mitigate this, in Figure II the upper bound and lower bound violations are value weighted using the number of call option open interest and put option open interest. In this case as well, the percentage of upper bound and lower bound violations increase on the earnings announcement day. Furthermore, on any given day the percentage of upper bound and lower bound violations weighted using put or call option open interest are higher than the percentage of violations weighted using the number of option pairs. This clearly shows that the violations are not due to illiquid options.

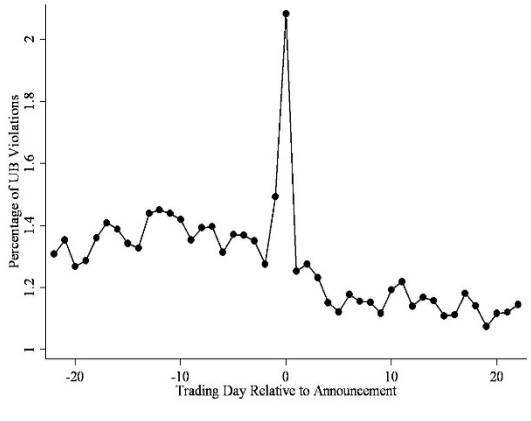
A stock can have numerous pairs of put and call options, but the open interest and trading volume on the options can be low and a number of the options can even have zero trading volume.

[4] This could be because of the following reasons: a) the option has a "special settlement", b) the midpoint of the bid/ask price is below intrinsic value, c) the vega of the option is below 0.5, d) the implied volatility calculation fails to converge, or e) the underlying price is not available.

Therefore using the number of options may not be a good method of weighting the violations. In order to mitigate this, in Figure II the upper bound and lower bound violations are value weighted using the number of call option open interest and put option open interest. In this case as well, the percentage of upper bound and lower bound violations increase on the earnings announcement day. Furthermore, on any given day the percentage of upper bound and lower bound violations weighted using put or call option open interest are higher than the percentage of violations weighted using the number of option pairs. Once again, these results show that the violations are not due to illiquid options.

Figure I
Percentage of Put-Call Parity Boundary Violations around Earnings Announcements

Panel A: Percentage of Upper Bound (UB) Violations



Panel B: Percentage of Lower Bound (LB) Violations

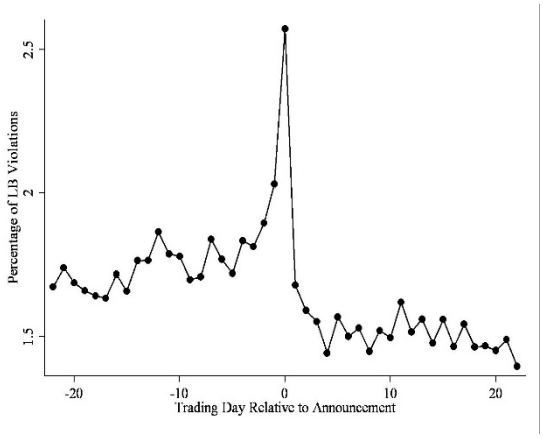
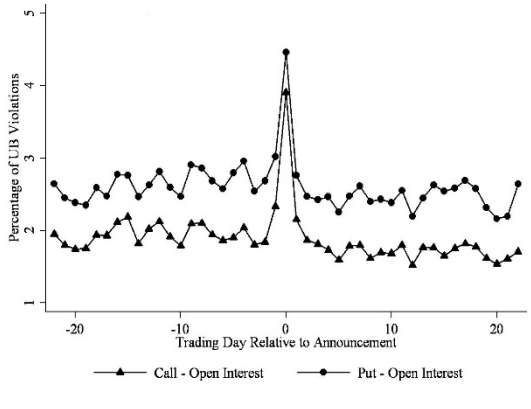
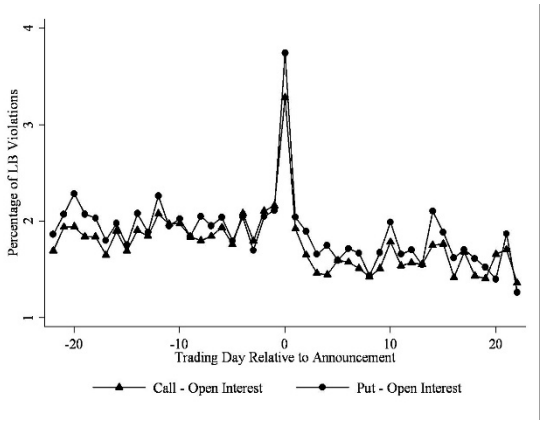


Figure II
Percentage of Put-Call Parity Boundary Violations around Earnings Announcements – Weighted using Call and Put Option Interest

Panel A: Percentage of Upper Bound (UB) Violations



Panel B: Percentage of Lower Bound (LB) Violations



It is interesting to note in Figure II that the percentage of upper bound violations value weighted using put option open interest is greater than the percentage of upper bound violations value weighted using call option open interest. This is because, when there is an upper bound violation, the stock price is greater than the option implied stock price, and in the presence of short sale constraints it becomes

difficult for the pessimistic investor to short sell the stock; therefore, they are more likely to buy put options. In the case of lower bound violations there are fewer arbitrage restrictions, so on any given day, the violations are the same whether we use call option open interest or put option open interest to weight the violations.

Table 2 reports the average magnitude of upper bound and lower bound violations on each trading day. For each option pair, I calculate the magnitude of upper bound and lower bound violations using equation (6) and equation (7) respectively. The average magnitude of the violations on each trading day is calculated by value-weighting the violations using the number of option pairs and option open-interest (both put and call). The results indicate that the magnitude of the upper bound and lower bound violations increase on the earnings announcement day and this result does not depend on the weighting measure used. On any given day, the magnitude of the upper bound violation is higher than the magnitude of the lower bound violation. This is because, due to the existence of short sale constraints, it is much harder to arbitrage upper bound violations as compared to lower bound violations. This result is consistent with the results of Ofek, Richardson, and Whitelaw (2004), who find that violations of put-call parity are asymmetric in the direction of short sale constraints.

Table 2

Panel A:	Average Magnitude of Upper Bound Violations - Value Weighted Measure								
Weighting	Trading Day Relative to Announcement								
	-20	-15	-10	-6	0	6	10	15	20
Number of Options	0.0069	0.0081	0.0111	0.0086	0.0135	0.0060	0.0058	0.0056	0.0064
Call Option Open Interest	0.0055	0.0076	0.0082	0.0086	0.0149	0.0062	0.0056	0.0054	0.0054
Put Option Open Interest	0.0065	0.0085	0.0099	0.0100	0.0151	0.0077	0.0071	0.0073	0.0074

Panel B:	Average Magnitude of Lower Bound Violations - Value Weighted Measure								
Weighting	Trading Day Relative to Announcement								
	-20	-15	-10	-6	0	6	10	15	20
Number of Options	0.0053	0.0052	0.0078	0.0051	0.0094	0.0037	0.0045	0.0055	0.0039
Call Option Open Interest	0.0029	0.0020	0.0042	0.0024	0.0076	0.0015	0.0021	0.0021	0.0014
Put Option Open Interest	0.0031	0.0020	0.0048	0.0026	0.0094	0.0016	0.0022	0.0020	0.0015

The "Jackknife" method is used to test and see if the increase in the percentage of violations on the earnings announcement day is statistically significant. Table 3 reports the "Jackknife" test results for the change in the percentage of violations before and after the earnings announcement day. The change in the percentage of upper bound and lower bound violations before the earnings announcement for each firm quarter is calculated as follows:

$$chg\_b\_UB = pc\_ubba_0 - \frac{1}{5}\sum_{t=-10}^{t=-6}(pc\_ubba_t) \tag{8}$$

$$chg\_b\_LB = pc\_lbba_0 - \frac{1}{5}\sum_{t=-10}^{t=-6}(pc\_lbba_t) \tag{9}$$

where *pc_ubba* and *pc_lbba* refer to the percentage of upper bound and lower bound violations for each firm quarter on a given day. This percentage is calculated using the number of put-call option pairs, option open-interest and option volume. Subscript t refers to the trading days in relation to the earnings announcement day. I examine the increase in the percentage of violations on the day of the announcement as compared to the mean percentage of violations from day 6 to day 10 before the

announcement. Similarly, I also calculate the change in the percentage of upper bound and lower bound violations after the earnings announcement for each firm quarter. In this case, I calculate the mean percentage of violations from day 6 to day 10 after the announcement day. The results in Table 3 indicate that the percentage of put-call parity violations significantly increases on the announcement day and significantly decreases after the announcement day. The results remain significant irrespective of the weighting measure used to calculate the percentage of violations.

Table 3
"Jackknife" Test for the Increase in Percentage of Violations on the Earnings Announcement Day

Panel A:	Percentage of UB Violations on day 0 - Average Percentage of UB Violations from day 6 to day 10 *before* the announcement day.				
Weighting used for Percentages	Obs.	Mean	Jackknife P-value	95% Conf. Interval	
Number of Options	35648	0.626%	0.000	0.531%	0.721%
Call Option Open Interest	35356	0.776%	0.000	0.658%	0.893%
Put Option Open Interest	34386	0.877%	0.000	0.747%	1.007%
Call Option Volume	28840	1.244%	0.000	1.064%	1.424%
Put Option Volume	21351	2.274%	0.000	2.014%	2.534%
Panel B:	Percentage of UB Violations on day 0 - Average Percentage of UB Violations from day 6 to day 10 *after* the announcement day.				
Weighting used for Percentages	Obs.	Mean	Jackknife P-value	95% Conf. Interval	
Number of Options	35661	0.740%	0.000	0.647%	0.833%
Call Option Open Interest	35373	0.895%	0.000	0.779%	1.011%
Put Option Open Interest	34454	1.092%	0.000	0.966%	1.219%
Call Option Volume	28881	1.388%	0.000	1.208%	1.568%
Put Option Volume	21398	2.668%	0.000	2.412%	2.924%
Panel C:	Percentage of LB Violations on day 0 - Average Percentage of LB Violations from day 6 to day 10 *before* the announcement day.				
Weighting used for Percentages	Obs.	Mean	Jackknife P-value	95% Conf. Interval	
Number of Options	35648	0.639%	0.000	0.518%	0.759%
Call Option Open Interest	35356	0.831%	0.000	0.682%	0.980%
Put Option Open Interest	34386	0.846%	0.000	0.687%	1.005%
Call Option Volume	28840	1.388%	0.000	1.161%	1.615%
Put Option Volume	21351	1.384%	0.000	1.110%	1.658%
Panel D:	Percentage of LB Violations on day 0 - Average Percentage of LB Violations from day 6 to day 10 *after* the announcement day.				
Weighting used for Percentages	Obs.	Mean	Jackknife P-value	95% Conf. Interval	
Number of Options	35661	0.95%	0.000	0.829%	1.069%
Call Option Open Interest	35373	1.30%	0.000	1.154%	1.452%
Put Option Open Interest	34454	1.20%	0.000	1.038%	1.355%
Call Option Volume	28881	2.21%	0.000	1.988%	2.434%
Put Option Volume	21398	1.93%	0.000	1.659%	2.204%

6.2. Put-call parity violations and post-announcement drift

In this section, I test the hypothesis that upper bound violations predict negative stock returns

and lower bound violations predict positive stock returns. I specifically examine the cumulative size-adjusted returns after the earnings announcement day. Table 4 reports the size-decile adjusted returns on day 0 and the cumulative size-decile adjusted returns from day 1 to day 10 after the earnings announcement day.

Table 4
Post-Announcement Returns

Panel A:	Firm Quarters which do not have an increase in UB or LB violations on the announcement day			
No. of Observations: 29437				
Variable	Mean	Std.Err.	95% Conf. Interval	
Day 0	0.0011	0.0004	0.0004	0.0018
Day 1	-0.0035	0.0005	-0.0044	-0.0026
Day 2	-0.0041	0.0005	-0.0052	-0.0031
Day 3	-0.0058	0.0006	-0.0069	-0.0046
Day 4	-0.0061	0.0006	-0.0074	-0.0049
Day 5	-0.0059	0.0007	-0.0072	-0.0046
Day 6	-0.0057	0.0007	-0.0070	-0.0043
Day 7	-0.0059	0.0007	-0.0073	-0.0045
Day 8	-0.0059	0.0008	-0.0074	-0.0044
Day 9	-0.0059	0.0008	-0.0074	-0.0043
Day 10	-0.0052	0.0008	-0.0068	-0.0036
Panel B:	Firm Quarters which have an increase in UB violations on the announcement day			
No. of Observations: 2336				
Variable	Mean	Std.Err.	95% Conf. Interval	
Day 0	0.0132	0.0014	0.0103	0.0160
Day 1	-0.0162	0.0019	-0.0199	-0.0124
Day 2	-0.0196	0.0023	-0.0241	-0.0151
Day 3	-0.0230	0.0024	-0.0277	-0.0182
Day 4	-0.0227	0.0026	-0.0278	-0.0176
Day 5	-0.0232	0.0027	-0.0285	-0.0180
Day 6	-0.0238	0.0028	-0.0293	-0.0183
Day 7	-0.0223	0.0030	-0.0281	-0.0165
Day 8	-0.0226	0.0030	-0.0286	-0.0166
Day 9	-0.0227	0.0032	-0.0289	-0.0164
Day 10	-0.0240	0.0033	-0.0304	-0.0176
Panel C:	Firm Quarters which have an increase in LB violations on the announcement day			
No. of Observations: 3658				
Variable	Mean	Std.Err.	95% Conf. Interval	
Day 0	-0.0096	0.0012	-0.0119	-0.0072
Day 1	0.0066	0.0015	0.0036	0.0096
Day 2	0.0058	0.0018	0.0024	0.0093
Day 3	0.0042	0.0019	0.0004	0.0079
Day 4	0.0029	0.0020	-0.0010	0.0068
Day 5	0.0027	0.0021	-0.0014	0.0069
Day 6	0.0030	0.0022	-0.0014	0.0073
Day 7	0.0030	0.0023	-0.0015	0.0075
Day 8	0.0037	0.0024	-0.0011	0.0085
Day 9	0.0021	0.0025	-0.0028	0.0070
Day 10	0.0025	0.0026	-0.0026	0.0076

Table 4, Panel A shows the post-announcement returns for firm-quarters that do not have an increase in upper bound or lower bound violations on the earnings announcement day. The post-announcement returns for this sample are negative, but the magnitude is much smaller than the

magnitude of the post-announcement returns for firms with an increase in upper bound violations on the announcement day. Table 4, Panel B shows the post-announcement returns for firm-quarters that have an increase in upper bound violations on the announcement day. Here the announcement returns are significantly positive and the post-announcement returns are significantly negative. There is a clear reversal in stock returns for firm-quarters that have an increase in upper bound violations. There is also a drift in the post-announcement returns for up to 10 days after the announcement day.

Table 5
Post-Announcement Returns for Firm Quarters with an Increase in Upper Bound Violations on the Announcement Day

Panel A:	Firm Quarters which have a small increase in UB violations			
No. of Observations: 1115				
Variable	Mean	Std.Err.	95% Conf. Interval	
Day 0	0.0143	0.0020	0.0104	0.0183
Day 1	-0.0093	0.0026	-0.0144	-0.0043
Day 2	-0.0128	0.0030	-0.0187	-0.0068
Day 3	-0.0164	0.0032	-0.0226	-0.0102
Day 4	-0.0150	0.0035	-0.0218	-0.0081
Day 5	-0.0142	0.0036	-0.0213	-0.0071
Day 6	-0.0145	0.0038	-0.0220	-0.0070
Day 7	-0.0128	0.0040	-0.0206	-0.0050
Day 8	-0.0128	0.0042	-0.0209	-0.0046
Day 9	-0.0138	0.0043	-0.0223	-0.0053
Day 10	-0.0153	0.0045	-0.0240	-0.0066
Panel B:	Firm Quarters which have a medium increase in UB violations			
No. of Observations: 449				
Variable	Mean	Std.Err.	95% Conf. Interval	
Day 0	0.0076	0.0033	0.0011	0.0140
Day 1	-0.0201	0.0043	-0.0285	-0.0116
Day 2	-0.0233	0.0053	-0.0338	-0.0129
Day 3	-0.0281	0.0056	-0.0392	-0.0171
Day 4	-0.0265	0.0057	-0.0378	-0.0152
Day 5	-0.0281	0.0060	-0.0399	-0.0163
Day 6	-0.0310	0.0064	-0.0435	-0.0184
Day 7	-0.0313	0.0069	-0.0449	-0.0178
Day 8	-0.0316	0.0070	-0.0453	-0.0178
Day 9	-0.0303	0.0073	-0.0446	-0.0161
Day 10	-0.0308	0.0075	-0.0455	-0.0161
Panel C:	Firm Quarters which have a large increase in UB violations			
No. of Observations: 772				
Variable	Mean	Std.Err.	95% Conf. Interval	
Day 0	0.0148	0.0026	0.0096	0.0199
Day 1	-0.0237	0.0037	-0.0310	-0.0164
Day 2	-0.0273	0.0044	-0.0359	-0.0188
Day 3	-0.0294	0.0047	-0.0387	-0.0202
Day 4	-0.0315	0.0050	-0.0414	-0.0216
Day 5	-0.0334	0.0051	-0.0435	-0.0234
Day 6	-0.0330	0.0053	-0.0433	-0.0227
Day 7	-0.0307	0.0055	-0.0416	-0.0199
Day 8	-0.0316	0.0056	-0.0426	-0.0206
Day 9	-0.0312	0.0060	-0.0429	-0.0194
Day 10	-0.0325	0.0061	-0.0445	-0.0205

In Table 5, the firm-quarters are spilt into three groups based on the increase in the percentage of upper bound violations on the earnings announcement day. I find that the negative post-announcement returns are higher for firm-quarters that have a large increase in the percentage of upper bound violations. Furthermore, the drift in post-announcement returns is also much stronger for firm-quarters with a large increase in the percentage of upper bound violations. These results clearly indicate that upper bound violations predict negative post-announcement returns.

Table 6
Post-Announcement Implied Volatility Spread

Panel A:	Firm Quarters which do not have an increase in UB or LB violations on the announcement day			
No. of Observation: 29724				
Variable	Mean	Std.Err.	95% Conf. Interval	
Day 0	-0.0090	0.0005	-0.0101	-0.0080
Day 1	-0.0049	0.0006	-0.0060	-0.0037
Day 2	-0.0062	0.0006	-0.0073	-0.0050
Day 3	-0.0068	0.0006	-0.0080	-0.0057
Day 4	-0.0074	0.0005	-0.0085	-0.0063
Day 5	-0.0070	0.0005	-0.0081	-0.0060
Day 6	-0.0074	0.0006	-0.0086	-0.0062
Day 7	-0.0063	0.0005	-0.0074	-0.0052
Day 8	-0.0068	0.0005	-0.0079	-0.0058
Day 9	-0.0065	0.0006	-0.0076	-0.0054
Day 10	-0.0069	0.0005	-0.0079	-0.0058
Panel B:	Firm Quarters which have an increase in UB violations on the announcement day			
No. of Observation: 2369				
Variable	Mean	Std.Err.	95% Conf. Interval	
Day 0	-0.1480	0.0061	-0.1600	-0.1360
Day 1	-0.0238	0.0026	-0.0288	-0.0187
Day 2	-0.0334	0.0031	-0.0394	-0.0274
Day 3	-0.0282	0.0028	-0.0336	-0.0227
Day 4	-0.0266	0.0025	-0.0315	-0.0217
Day 5	-0.0289	0.0034	-0.0356	-0.0222
Day 6	-0.0270	0.0026	-0.0321	-0.0219
Day 7	-0.0297	0.0036	-0.0367	-0.0227
Day 8	-0.0292	0.0033	-0.0357	-0.0228
Day 9	-0.0261	0.0031	-0.0321	-0.0201
Day 10	-0.0246	0.0028	-0.0300	-0.0191
Panel C:	Firm Quarters which have an increase in LB violations on the announcement day			
No. of Observation: 3685				
Variable	Mean	Std.Err.	95% Conf. Interval	
Day 0	0.0948	0.0025	0.0900	0.0997
Day 1	-0.0039	0.0019	-0.0077	-0.0001
Day 2	0.0079	0.0020	0.0040	0.0118
Day 3	0.0062	0.0017	0.0029	0.0096
Day 4	0.0044	0.0018	0.0009	0.0078
Day 5	0.0042	0.0017	0.0009	0.0076
Day 6	0.0015	0.0018	-0.0020	0.0051
Day 7	0.0033	0.0018	-0.0001	0.0068
Day 8	0.0026	0.0016	-0.0006	0.0057
Day 9	0.0028	0.0016	-0.0004	0.0060
Day 10	0.0016	0.0016	-0.0014	0.0047

Table 4, Panel C reports the post-announcement returns for firm-quarters that have an increase in lower bound violations. Here the announcement returns are significantly negative and the post-announcement returns are significantly positive for up to three days. The magnitude of the post announcement returns is much smaller for the sample of firms with lower bound violations compared to the sample of firms with upper bound violations. Furthermore, firms with lower bound violations do not have drift in post-announcement returns. This result is consistent with the magnitude of the lower bound violations also being much smaller. Lower bound violations occur when the stock price is less than the option-implied price. Unlike the upper bound violation, in this case it is much easier for arbitragers to take advantage of the arbitrage opportunity since they do not face any short sale constraints. Therefore, the private information will be incorporated into the stock price much sooner.

In order to further examine these violations I look at the put-call implied volatility spread on and after the earnings announcement day. The implied volatility spread is calculated as the difference between the call option implied volatility and the put option implied volatility. Here I use 30 day standardized call and put option implied volatility to determine the implied volatility spread. OptionMetrics constructs a set of standardized at-the-money forward options via interpolation for each underlying series and then calculates implied volatilities for options that have 30, 60, 90, 182 and 365 days to expirations.

In Table 6, Panel A I first examine the implied volatility spread for firms that do not have an increase in upper bound or lower bound violations on the announcement day. In this sample, the put options are overvalued relative to call options on any given day. Table 6, Panel B shows the results for firms that have an increase in upper bound violations on the announcement day. The put options are significantly overvalued relative to call options on the day of the announcement. For the post-announcement period they remain overvalued, but the magnitude drops significantly. This result is consistent with investors buying more put options in the presence of short sale constraints. In the case of lower bound violations (Table 6, Panel C), the call options are overvalued relative to put options on the day of the announcement. However, this magnitude is much smaller compared to the implied volatility spread for the sample of firms with upper bound violations.

6.3. Firm specific characteristics and put-call parity violations around earnings announcements

In order to examine the effects of firm-specific characteristics on the increase in put- call parity violations around earnings announcements, I first sort the firm-quarters into three groups based on the proxies used for asymmetric information and ease of hiding transactions. I then perform the "Jackknife" test for each of the three groups. I use equations (11) and (12) to determine the increase in upper bound and lower bound violations before and after the earnings announcement day. The percentage of violations used for the "Jackknife" test is value weighted using both call option open interest and put option open interest. I also do a t-test to test for the difference in the increase in violations on the announcement day across the various groups.

6.4. Empirical proxy for asymmetric information

In this section, I test the hypothesis that the increase in put-call parity boundary violations on the earnings announcement day is greater for growth firms than for value firms. Book-to-market value has been used as a measure of the growth options of the firm, and firms with more growth opportunities are associated with greater information asymmetry. The book-to-market value is defined as the book value of equity divided by the market value of equity. The book equity is the book value of shareholders' equity, plus balance sheet deferred taxes and investment tax credit (if available) minus the book value of preferred stock. The market value of equity is calculated as the closing stock price at the end of the second month of the firm quarter multiplied by the number of shares outstanding at the end of the firm quarter.

I first sort the firm-quarters into three groups based on the book-to-market value and then calculate the increase in upper bound and lower bound violations before and after the earnings announcement day. The violations are value weighted based on the level of call option open interest and put option open interest. Table 7 reports the "Jackknife" test results for the peak in violations on the earnings

announcement day for each of the three groups. Panel A and Panel C in Table 7 test for the increase in the percentage of upper bound and lower bound violations on the earnings announcement day. Panel B and D in Table 7 test for the decrease in the percentage of upper bound and lower bound violations after the earnings announcement day.

Table 7
Book-to-Market Sorting - "Jackknife" Test for the Increase in Percentage of Violations on the Earnings Announcement Day

Panel A:	Percentage of UB Violations on day 0 - Average Percentage of UB Violations from day 6 to day 10 *before* the announcement day.							
Weighting used for Percentages	Low BM (1)		Medium BM (2)		High BM (3)		Low - High	
	Mean	Jackknife P-value	Mean	Jackknife P-value	Mean	Jackknife P-value	Diff. in Mean	P-value
Call Option Open Interest	2.626%	0.000	1.585%	0.000	0.844%	0.141	1.783%	0.003
Put Option Open Interest	2.601%	0.000	1.520%	0.000	0.169%	0.835	2.432%	0.005
Panel B:	Percentage of UB Violations on day 0 - Average Percentage of UB Violations from day 6 to day 10 *after* the announcement day.							
Weighting used for Percentages	Low BM (1)		Medium BM (2)		High BM (3)		Low - High	
	Mean	Jackknife P-value	Mean	Jackknife P-value	Mean	Jackknife P-value	Diff. in Mean	P-value
Call Option Open Interest	2.928%	0.000	1.894%	0.000	0.723%	0.085	2.206%	0.001
Put Option Open Interest	3.029%	0.000	1.876%	0.000	-0.290%	0.708	3.319%	0.000
Panel C:	Percentage of LB Violations on day 0 - Average Percentage of LB Violations from day 6 to day 10 *before* the announcement day.							
Weighting used for Percentages	Low BM (1)		Medium BM (2)		High BM (3)		Low - High	
	Mean	Jackknife P-value	Mean	Jackknife P-value	Mean	Jackknife P-value	Diff. in Mean	P-value
Call Option Open Interest	1.504%	0.000	1.632%	0.000	0.896%	0.121	0.608%	0.142
Put Option Open Interest	2.149%	0.000	2.015%	0.000	0.682%	0.327	1.467%	0.056
Panel D:	Percentage of LB Violations on day 0 - Average Percentage of LB Violations from day 6 to day 10 *after* the announcement day.							
Weighting used for Percentages	Low BM (1)		Medium BM (2)		High BM (3)		Low - High	
	Mean	Jackknife P-value	Mean	Jackknife P-value	Mean	Jackknife P-value	Diff. in Mean	P-value
Call Option Open Interest	1.860%	0.000	1.813%	0.000	1.265%	0.000	0.595%	0.131
Put Option Open Interest	2.282%	0.000	2.157%	0.000	1.447%	0.016	0.835%	0.167

Consistent with my hypothesis, the results show that both the upper bound and lower bound violations significantly peak on the earnings announcement day for firm-quarters with low book-to-market (growth firms). On the earnings announcement day, the percentage of upper bound (lower bound) violations increases on average by 2.626% (1.504%) for low book-to-market firms, and for high book-to-market firms, the percentage of upper bound (lower bound) violations increases by

only 0.844% (0.896%).[5] The t-test results indicate that the increase in upper bound violations is significantly greater for low book-to-market firms compared to high book-to-market firms. Furthermore, the increase in the percentage of upper bound and lower bound violations is not statistically significant for high book-to-market firms. These results show that put-call parity boundary violations increase more significantly for firms with more asymmetric information (low book-to-market or growth firms).

6.5. Empirical proxy for ease of hiding transactions

In this section I test the hypothesis that the increase in put-call parity boundary violations on the announcement day are greater for big firms than for small firms.

Table 8
Market Equity Sorting - "Jackknife" Test for the Increase in Percentage of Violations on the Earnings Announcement Day

Panel A:	Percentage of UB Violations on day 0 - Average Percentage of UB Violations from day 6 to day 10 *before* the announcement day.							
Weighting used for Percentages	Small ME (1)		Medium ME (2)		Big ME (3)		Big - Small	
	Mean	Jackknife P-value	Mean	Jackknife P-value	Mean	Jackknife P-value	Diff. in Mean	P-value
Call Option Open Interest	0.468%	0.068	1.007%	0.018	2.194%	0.000	1.727%	0.000
Put Option Open Interest	0.689%	0.151	0.722%	0.402	1.929%	0.000	1.240%	0.020
Panel B:	Percentage of UB Violations on day 0 - Average Percentage of UB Violations from day 6 to day 10 *after* the announcement day.							
Weighting used for Percentages	Small ME (1)		Medium ME (2)		Big ME (3)		Big - Small	
	Mean	Jackknife P-value	Mean	Jackknife P-value	Mean	Jackknife P-value	Diff. in Mean	P-value
Call Option Open Interest	1.151%	0.000	1.321%	0.000	2.370%	0.000	1.220%	0.007
Put Option Open Interest	1.787%	0.002	1.416%	0.004	2.053%	0.000	0.266%	0.361
Panel C:	Percentage of LB Violations on day 0 - Average Percentage of LB Violations from day 6 to day 10 *before* the announcement day.							
Weighting used for Percentages	Small ME (1)		Medium ME (2)		Big ME (3)		Big - Small	
	Mean	Jackknife P-value	Mean	Jackknife P-value	Mean	Jackknife P-value	Diff. in Mean	P-value
Call Option Open Interest	0.950%	0.000	0.691%	0.000	1.537%	0.000	0.587%	0.069
Put Option Open Interest	1.127%	0.003	0.621%	0.007	1.943%	0.000	0.816%	0.082
Panel D:	Percentage of LB Violations on day 0 - Average Percentage of LB Violations from day 6 to day 10 *after* the announcement day.							
Weighting used for Percentages	Small ME (1)		Medium ME (2)		Big ME (3)		Big - Small	
	Mean	Jackknife P-value	Mean	Jackknife P-value	Mean	Jackknife P-value	Diff. in Mean	P-value
Call Option Open Interest	1.445%	0.000	1.039%	0.000	1.835%	0.000	0.390%	0.161
Put Option Open Interest	1.262%	0.001	0.933%	0.000	2.223%	0.000	0.961%	0.051

[5] The percentage of violations reported here is value weighted based on the number of call option open interest. The results do not change and remain significant even if put option open interest is used to calculate the percentage of violations (see Table 8).

I use the market equity of the firm as a proxy for ease of hiding transactions in the options market by informed traders. Here I assume that firms with high market equity have liquid options. I sort the firm-quarters into three groups based on the market equity of the firm. I find that on any given day, the percentage of violations is much higher for small firms than for big firms. In the case of upper bound violations the percentage of violations is around 6% for small firms and around 2% for large firms. This is because the violations in small firms are much harder to arbitrage, so on any given day, we will see higher violations. I do not find a significant peak in violations on the announcement day for small firms because informed traders in small firms are reluctant to trade in the options market due to low option liquidity for small firms.

Table 9
Book-to-Market and Market Equity Sorting - "Jackknife" Test for the Increase in Percentage of Violations on the Earnings Announcement Day

Panel A:	Percentage of UB Violations on day 0 - Average Percentage of UB Violations from day 6 to day 10 *before* the announcement day.							
Weighting used for Percentages	Low BM / Small ME		Low BM / Big ME		High BM / Small ME		High BM / Big ME	
	Mean	Jackknife P-value	Mean	Jackknife P-value	Mean	Jackknife P-value	Mean	Jackknife P-value
Call Option Open Interest	-0.283%	0.595	3.027%	0.000	0.972%	0.011	0.585%	0.266
Put Option Open Interest	-0.531%	0.649	3.001%	0.000	1.649%	0.016	-0.363%	0.716
Panel B:	Percentage of UB Violations on day 0 - Average Percentage of UB Violations from day 6 to day 10 *after* the announcement day.							
Weighting used for Percentages	Low BM / Small ME		Low BM / Big ME		High BM / Small ME		High BM / Big ME	
	Mean	Jackknife P-value	Mean	Jackknife P-value	Mean	Jackknife P-value	Mean	Jackknife P-value
Call Option Open Interest	1.195%	0.027	3.222%	0.000	1.064%	0.027	0.554%	0.300
Put Option Open Interest	1.729%	0.095	3.284%	0.000	1.759%	0.051	-0.845%	0.373
Panel C:	Percentage of LB Violations on day 0 - Average Percentage of LB Violations from day 6 to day 10 *before* the announcement day.							
Weighting used for Percentages	Low BM / Small ME		Low BM / Big ME		High BM / Small ME		High BM / Big ME	
	Mean	Jackknife P-value	Mean	Jackknife P-value	Mean	Jackknife P-value	Mean	Jackknife P-value
Call Option Open Interest	0.524%	0.120	1.649%	0.001	1.357%	0.003	0.847%	0.091
Put Option Open Interest	0.434%	0.216	2.338%	0.000	2.048%	0.018	0.574%	0.505
Panel D:	Percentage of LB Violations on day 0 - Average Percentage of LB Violations from day 6 to day 10 *after* the announcement day.							
Weighting used for Percentages	Low BM / Small ME		Low BM / Big ME		High BM / Small ME		High BM / Big ME	
	Mean	Jackknife P-value	Mean	Jackknife P-value	Mean	Jackknife P-value	Mean	Jackknife P-value
Call Option Open Interest	1.153%	0.001	1.984%	0.000	1.685%	0.000	1.236%	0.004
Put Option Open Interest	0.606%	0.181	2.462%	0.000	1.913%	0.027	1.495%	0.044

Table 8 reports the "Jackknife" test results for each of the three groups. The results show that both the upper bound and lower bound violations significantly peak on the earnings announcement day for firm-quarters with high market equity. On the earnings announcement day, the percentage of upper bound (lower bound) violations increases on average by 2.194% (1.537%) for high market equity firms and for low market equity firms the percentage of upper bound (lower bound) violations increases by only 0.468% (0.950%). The t-test results indicate that the increase in upper bound and lower bound violations is significantly higher for firms with high market equity.

Put-call parity violations increase on the announcement day because of asymmetric information and informed investors trading first in the options market. Therefore, I simultaneously sort the firms based on book-to-market and market equity. Consistent with my hypothesis, I find that firms with low book-to-market and high market equity (big-growth firms) have the greatest increase in violations on the announcement day. Table 9 reports the "Jackknife" test results, and it shows that both the upper bound and lower bound violations significantly peak on the earnings announcement day for firm-quarters with low book-to-market and high market equity. The percentage of upper bound (lower bound) violations using call option open interest increases significantly on the earnings announcement day, by 3.027% (1.649%) for firms with low book-to-market and high market equity. Here firms with low book-to-market and high market equity are firms that have a large number of informed traders and liquid options. For firms with low book-to-market and low market equity, the violations do not peak on the announcement day because even though these firms might have informed traders, they do not have enough liquidity in the options market for informed investors to trade.

7. Conclusions

Prior research on put-call parity violations has attributed the violations to informed trading in the options market and limits to arbitrage. The papers analyzing put-call parity violations do so either by calculating the early exercise premium on put options or by examining the implied volatility spread. One of the drawbacks of these papers is that their results are not model independent and they are no longer evaluating a no-arbitrage condition. Using a large data set, this is the first paper to document put-call parity boundary violations around earnings announcements. In doing so, this study extends the previous work on put-call parity violations and informed trading in the options market.

An earnings announcement is probably one of the most important sources of information released by the firm. When the firm announces its earnings, the market updates its belief about the true value of the firm by trading in stocks and options. If the options and the stock market are segmented, with the options market having informed investors, then the mispricing does not carry over to the options market. If there are several limits to arbitrage in the form of transaction costs and short-sale restrictions, etc., then the mispricing will not be corrected immediately. This will cause the stock price to drift away from its implied price in the options market, resulting in violations of put-call parity.

I find that there is a significant increase in the percentage of violations on the earnings announcement day and that these violations are not the result of illiquid options or transaction costs. Consistent with informed investors trading first in the options market, I find that upper bound violations predict negative stock returns and that lower bound violations predict positive stock returns. Growth firms are more likely to have more information-motivated investors and in order to hide their transactions, informed investors will trade in the options market only if the options are very liquid. Therefore, I find that put-call parity boundary violations peak on the earnings announcement day for firms with low book-to-market ratio and high market equity.

In summary, this study attributes the increase in violations on the earnings announcement day to the presence of informed investors in the options market who can interpret and analyze private information. This research is important because the evidence indicates the need for new option pricing theories that incorporate put-call parity violations, particularly around information

events. The paper sheds light on how information in earnings announcements is disseminated in the stock and option markets. Moreover, the findings suggest potentially profitable trading strategies that exploit the put-call parity violations around earnings announcements.

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