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Using Option Prices and Open Interest to Forecast Future Volatility of a Small Cap Biotech Security Facing a Binary Event

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Using Option Prices and Open Interest to Forecast Future Volatility of a Small Cap Biotech Security Facing a Binary Event

By

Chris Abbott

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By

Chris Abbott

We hereby certify that this Thesis submitted by Chris Abbott conforms to acceptable standards, and as such is fully adequate in scope and quality. It is therefore approved as the fulfillment of the Thesis requirements for the degree of Master of Science of Finance.

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Abstract

The purpose of this study is to determine the accuracy of price targets set by options traders for small cap biotech companies approaching a Food and Drug (FDA) event. The study also highlights whether or not an increase in open interest improves the accuracy of options traders target price estimates. The thesis for this paper states that the options estimates of future price movement are accurate predictors of the future price one day before the FDA event. This thesis studies small cap biotech stocks with an approaching FDA approval or advisory committee meeting for the time period of December 2007 to April 2013. The conclusions are that the price targets are significantly greater than the realized price, and that open interest does not significantly improve the accuracy of these contracts.

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CHAPTER I

INTRODUCTION

Overview of the Chapter

This chapter focuses on using at-the-money options prices and open interest to determine the future absolute price change of an underlying asset given a known binary event, such as a Prescription Drug User Fee Act (PDUFA) action date. A PDUFA action date is the final approval or rejection date for a therapy being sponsored for consideration for FDA approval. The chapter includes a discussion of the expected contributions and insights regarding the large percentage movement of the stock price of a biotech company on or around a known PDUFA date. The methodology for the study is discussed further in Chapter Three. Finally, I discuss the format of the remaining chapters. Please refer to the appendix on page 51 for a complete list of operational terms used throughout this research paper.

Option Pricing Theory

An option is the right, but not the obligation, to buy or sell an underlying asset at a predefined price, the Strike Price, at a pre-specified point in the future, the expiration month. Options generally expire on the third Saturday of each month, although there are options that expire weekly in some cases. Weekly options will not be the focus of this study. Options are broken into two broad categories, American and European. The distinction has nothing to do with where the securities trade but is instead focused on the ability to exercise the option. An American option allows the holder to exercise the option at any point up to and including the expiration date of the option. A European option gives the holder the option, but not the obligation, to exercise the security but only on the expiration date. This study focuses on one very small segment of the options market: the American style equity options of small cap biotech and medical device companies, primarily trading on the NASDAQ stock exchange.

The Black-Scholes Model is the most prominent method used to value options. The model makes the following key assumptions: (1) the stock price follows a log-normal distribution, (2) capital markets are perfect and competitive, (3) the option price is a function of the stock price and time to maturity, (4) the short-term interest rate and the variance of return are constant and stationary until maturity, (5) the option is a payout protected call option (Beckers, 1980, p. 364).

These assumptions restrict the applicability of this method when determining option prices with large movements in the underlying asset. Often the binary event that is created by a PDUFA or an FDA Advisory committee (ADCOM) decision will lead to stock price changes in excess of 20 to 30 percent in small cap biotech companies. These large price changes are difficult for the Black-Scholes Model to account for due to the finite variance distribution implied by a lognormal distribution. The Black-Scholes Model has gained prominence because the formula is easily calculated using observable variables. When modeling the fair value of an option contract, there are several methods that can be used and the Black-Scholes Model is a popular one. However, there are also several other common methods that are used to price options contracts.

In the 1979 article, "Options Pricing: a Simple Approach" Cox, Ross and Rubinstein (1979) introduced "the binomial method for the valuation of American options. These methods discretize both the time and state spaces in order to approximate the option price. The methods are very easy to implement and are quite flexible in that they can be easily adapted to price many nonstandard or exotic options" (Cox et al., 1979). The flexibility of the Cox-Ross Binomial

Model makes it a more appropriate for modeling large movements of the underlying stock than the Black-Scholes Model.

A third option pricing model put forward by Merton "explicitly admits jumps in the underlying security return process, and which may resolve the pricing discrepancies" (Ball & Torous, 1985, p.155) created when using either the Black-Scholes or Cox-Ross models. Merton's model tries to overcome the shortcomings of the other two models by allowing for either small or large changes in the underlying assets price. But it can only be used with accurate estimates of the jump probability. The jump probability is difficult to estimate, which is the primary drawback of the Merton (1973) Model.

In order to use the Merton Model, an accurate estimate of the probability of a jump in the underlying stock, is required. An accurate jump probability is inherently difficult to calculate (Jones, 1984,). In the context of this study the probability of a jump for this data set should be very close to one, because all of the study's observations are expected to have large price moves as a result of the outcome of the upcoming known binary event. The large probability of a jump in the price of a small cap biotech stock may cause the Merton Model to misprice the options.

Each of these three models adds value to the pricing of option contracts. For the purpose of this paper, I assume that the appropriate model is being used to price the options of the underlying biotech company. In other words, the options have been priced in such a way as to reflect the volatility expectations of informed traders given an upcoming known binary event. I make this assumption because my goal is to estimate the absolute price change of the underlying stock using the trading information of at-the-money call and put options three days before the event date. I am not attempting to find the most accurate way to estimate the price of a stock option, which relieves me from making a judgment on the accuracy of the pricing model used.

Small-Cap Biotech Characteristics

There are many opinions regarding what constitutes a small cap stock. For this paper a small cap stock is defined as a company having a Market Capitalization (Stock Price * Shares Outstanding) of $250 million to $4 billion. Small cap stocks are traditionally more volatile than their medium and large cap peers due to the limited visibility of the companies and often low levels of liquidity in the market for their shares.

This paper looks specifically at small cap biotech and medical device companies because they generally have few, if any, stable revenue generating therapies and are therefore much more dependent on favorable binary event outcomes to maintain and increase stock prices. The high degree of dependency on positive news implies large price swings, either up or down, caused by binary events such as PDUFA dates and ADCOM (advisory committee) meetings.

The companies will often reveal PDUFA action dates to the public well in advance of the final decision, and ADCOM meetings are posted on the FDA's website, also well in advance. This advanced notice provides a unique trading opportunity for informed investors in the biotech market. The availability of options allows speculators to make relatively safe leveraged bets on the outcome of these binary events. The relative safety of these levered bets stems from the fact that the downside risk is limited to the premium paid for the call or put option.

Further compounding the risk, and therefore the volatility of these companies is the fact that they tend to burn significant cash during the research phase of therapy development. The high cost of bringing a drug to market - some estimates are as high as $2 billion - means that a small cap biotechnology company will only have a handful of therapies in late stage clinical trials. An approved therapy can be the difference between years of strong cash flow generation or years of consistent equity dilution, typically through the issuance of new stock, in order to keep the company alive.

Price Discovery Using Option Prices and Open Interest

The ability for options traders to affect the underlying asset's price has been the subject of numerous studies in finance. How options are traded leading up to an earnings announcement is a topic that has been the subject of strong research interest. For example, Lee and Amin ("Option Trading," 1994) found that in the four days prior to an earnings announcement, options volume increases by as much as 10 percent. Furthermore, "the direction of this preannouncement trading foreshadows subsequent earnings news. Specifically, we find option traders initiate a greater proportion of long (short) positions immediately before "good" ("bad") earnings news." They conclude that "collectively, the evidence shows option traders participate generally in price discovery (the incorporation of private information in price), and more specifically in the dissemination of earnings news ("Option Trading," 1994)."

This study shows how informed investors use the options market to impound information into stock prices, especially given a known event. The price discovery effect of options leading up to earnings announcement is a similar concept to the topic of this thesis, except I focus on the price discovery of options leading up to an FDA event. The primary difference between this study and studies on volatility leading up to an earnings announcement is that the binary event in this study is FDA action dates or ADCOM committee meetings votes.

Open interest in the options market is the number of contracts outstanding. In order for open interest to change, one buyer and one seller must enter or leave the market. Open interest provides a picture of the trading in each option. This information is useful to option market participants because it provides a view of trader sentiment. Schlag and Stoll (2004) found that "positive options volume (buy calls and sell puts, or calls bought minus calls sold) has a contemporaneous positive price effect [on the underlying asset]," whereas, "negative volume has the corresponding negative price effect [on the underlying asset] (Schlag & Stoll, 2004). This shows that the selling or buying pressure in the options market has an effect in driving changes in the underlying asset price.

Lee and Amin's article ("Option Trading," 1994) discussing the effect of option trading, i.e. open interest and option prices, on earnings news dissemination may be applicable to the focus of this thesis, option market participants trading on FDA news dissemination. In Lee and Amin's study they found "some evidence that increased preannouncement option trading reflects more than trader response to volatility risk. That is, option traders anticipate not only the magnitude of a price reaction, but also its direction ("Option Trading," 1994)." Given that there is some evidence to reflect option traders can anticipate earnings releases, can options traders also effectively anticipate outcomes of these binary events in high volatility scenarios?

<u>Research Questions</u>

The primary research question of this study is whether or not the information contained in option prices and open interest can be used to estimate the future absolute price change of a small cap stock leading up to a binary event. This is very similar to studies that look at the price discovery of options leading up to an earnings announcement. The primary difference is that instead of an earnings announcement, we are concentrating on an FDA announcement. I also look at the liquidity premium associated with trading in these markets. Some small cap biotech stocks have very few options traded on them, leading to low open interest and wider bid-ask spreads. This paper will determine what effect open interest has on the accuracy of the price discovery mechanism in options markets.

Scope and Limitations of the Study

This study has a very narrow focus. It draws on work from other research on option price discovery. However, this is believed to be the first study to explore the extent of price discovery provided by the options market leading up to an FDA event. The narrow focus of this paper adds considerable limitations to the applicability of the results to other situations. The applicability across asset classes and industries may be limited due to the unique nature of a biotech stock with an impending FDA event date.

There are very few instances in the market when an investor knows with a high degree of certainty when an event will occur that could immediately change the stock price by 50 percent or more in either direction. As a result, the options market for biotech stocks provides an interesting test of the price discovery and price efficiency of option trading. However the liquidity of the market is cause for some concern. In some instances very little trading occurs in these options other than the days leading up to and immediately following an FDA action date.

The remainder of this study is organized as follows. In Chapter Two I discuss the work of others who studied the price discovery of options leading up to a known event, primarily earnings dissemination. I also elaborate on the three options pricing models I mentioned in the introduction. In Chapter Three I discuss the methodology I plan to use to test the predictability of future volatility following a small cap biotech binary event. Chapter Four will go on to discuss the data collection and presentation used for this study. Chapter Five will briefly discuss the methodology employed, as well as the methods used to clean and prepare the data. In Chapter Six I will finish with a review of the conclusions of this study and suggestions for further research.

CHAPTER II

REVIEW OF LITERATURE

The History of Options Valuation

In 1973, the Chicago Board Options Exchange (CBOE) was founded. The CBOE is the first market place that allows investors to trade standardized and listed options. Put options did not appear right away and were added to the exchange in 1977. Since those early days, option trading has become progressively more common and is primarily used as a tool to hedge risk. There is also an argument that options, in certain circumstances, may allow a trader to gain an equivalent exposure to an asset with relatively lower transaction costs. The CBOE is a major part of the growth in options trading and the literature that has developed from it. Academic literature also talks about how informed investors may prefer to trade using options due to the inherent leverage of the instrument.

Prior to Black and Scholes' (1973) seminal work, *The Pricing of Options and Corporate Liabilities,* the literature on pricing options centered on the valuation of warrants. Black and Scholes (1973) noted that the prevailing warrant pricing theories of the time, including, Sprenkle (1961); Ayres (1963); Bones (1964); Samuelson (1965); Baumol, Malkiel and Quandt (1966) and Chan (1970), "all produced valuation formulas of the same general form. Their formulas, however, are not complete, since they involved one or more arbitrary parameters" (Black & Scholes, 1973, p.639). Often the arbitrary values are unknown in both form and quantity. Black and Scholes went on to develop an option pricing model that allowed an investor "to create a hedged position, consisting of a long position in the stock and a short position in the option, whose value will not depend on the price of the stock, but will depend only on time and the values of known constraints (Black & Scholes, 1973, p.640)." This formula was a significant addition to the knowledge involving the pricing of equity options because it was a closed form solution to options pricing.

Despite the monumental leap forward provided by the Black-Scholes Model, there are several limitations that restrict its usefulness in the real markets. In order for the model to accurately price an option, there are several assumptions that must hold. According to Fischer Black, the Black-Scholes formula "gives the value of a call option for any stock price and time to maturity. The simplest version of the formula assumes that the short-term interest rate and the volatility of the stock never change, and that the stock pays no dividends. There are five numbers we need to calculate an option value: (1) the stock price, (2) the time to maturity, (3) the exercise price, (4) the interest rate, and (5) the volatility of the stock" (Black, 1975, p.36). Furthermore, the original form of the model is only useful for European Options, which only provide trading rights on the expiration date.

In the same article, Black (1975) went on to propose an adjustment to the original Black-Scholes Model (1973) that tried to explain the increased premium paid for the flexibility offered by American Options, which can be exercised prior to the maturity date. The solution offered was an ad-hoc modification to the original formula that allowed the formula to price a pseudo American call option. The pseudo call option is an iterative process computed with a number of European call option prices. Each option is priced using a modified time to maturity, achieved by assuming that the option will be exercised at one of the ex-dividend dates for the company. The future value is then discounted back to the present discounted at the risk-free rate. In each of the calculations, the time to exercise is shortened to the ex-dividend date causing the time to maturity to decrease as well as the price of the option. The pseudo call option price is calculated as the maximum price developed over a range of possible input values using the Black-Scholes (1973) European call option formula.

Geske and Roll (1984) state that "the pseudo-American call value will be less than the actual American [call] value because the pseudo method does not reflect the full opportunities of the American call holder. The American call value reflects the conditional probability (conditional on the stock price) of exercising prematurely at each ex-dividend date, rather than certain early exercise or certain no exercise" (Geske & Roll, 1984, p. 444).

Building on the earlier work by Black and Scholes (1973), in 1979, Cox et al., introduced a binomial method to price options. The trio showed that they could price options working recursively from the final expected price of the option using a binomial tree. The binomial tree allows for two possible price movements, up or down, where the value in the up move, or node, and the value in the down node are discounted back to the current period at the appropriate discount rate. Once discounted at the appropriate rate, the two nodes are weighted using the relative probability of an up or down move in the option price (Cox et al., 1979). Macbeth and Merville (1980) found that the "Cox valuation model fits market prices of call options significantly better than the Black-Scholes Model" (Macbeth & Merville, 1980, p. 285).

Geske and Johnson describe the model developed by Black and Scholes as a "formula for a European put when the stock price follows geometric Brownian motion" (Geske & Johnson, 1984, p. 1511) Taking this into consideration, Geske and Johnson went on to develop a model known as The-Two Point Geske & Johnson Method. "The American option formula given in Geske and Johnson (1984) is an exact representation of the option value in terms of an infinite series" (Broadie & Detemple, 1996, p. 1230). Furthermore, this method "allows the use of an evaluation technique resulting in a significant reduction in the number of critical stock price computations necessary for penny accuracy and thus enhances computational efficiency" (Geske & Johnson, 1984, p. 1522).

In 1991 Breen puts forth a model known as the accelerated binomial method, which is a streamlined version of the Cox-Ross binomial method. According to Broadie and Detemple "the main computational effort in this routine involves multiplication. The work is easily shown to be $\sim 7/12n^2$. The work in the binomial routine is $\sim n^2$ (2 multiplications at $n^2/2$ nodes). Thus the accelerated binomial is faster than the binomial routine for the same n" (Broadie & Detemple, 1996, p. 1240).

There have also been several versions of trinomial methodologies to value options. Notably, Kamrad and Ritchken (1991) proposed a trinomial model that worked very similarly to the Cox-Ross Model. The primary addition was that the trinomial model uses three nodes instead of two. The trinomial method adds a middle node to the up and down nodes, provided by the Cox-Ross Model. Each of the three nodes is discounted by the appropriate interest rate and then each node is weighted using the appropriate method to develop the price for the previous node, just like in the binomial model.

Carr & Faguet (1994) proposed the Method of Lines to value option contracts. The Method of Lines is used to determine the numerical value of American options while considering the inherent early expiration problem. The Method of Lines "has been applied over the years to a number of one- and multi-dimensional free boundary problems arising in science and engineering" (Meyer & Hoek, 1994, p. 1). Goldenberg and Schmidt (1995) discussed the advantages of the Method of Lines, showing that the approach is at least as fast as alternative methods and can be implemented very accurately (Goldenberg & Schmidt, 1995).

Broadie and Detmeple (1996) introduced a new method to value the upper and lower bounds of American option prices. The pair compared their method to several other option valuation models and found that the model was a more accurate pricing model than a 1,000 step binomial model. Interestingly, not only is the Upper/Lower bound method somewhat more accurate than most other option pricing mechanisms, it is also much simpler and faster to produce than similar pricing models. "Both lower and upper bound information, has a root mean squared (RMS) relative error of 0.02 percent on a sample that represents a wide range of option parameters. This RMS error is slightly better than the RMS error of a 1,000-step binomial tree. Furthermore, the LUBA approximation can be computed as fast as a 50-step binomial tree (or about 500 times faster than a 1,000-step binomial tree)… Furthermore, these two approximations are sufficiently simple that they can be computed in a spreadsheet (Broadie & Detemple, 1996, p. 1212)."

Like the call option, the put option has been the subject of a significant amount of research devoted to developing a pricing model for American style puts. As early as 1973, Robert Merton showed in *The Theory of Rational Option Pricing*, that American puts are more difficult to value than European puts. This is because there is consistently a positive probability that the American put option will get exercised (Merton, 1973). Despite the challenges in pricing American put options the literature and primary pricing methods all have relatively simple adjustments to allow for the pricing of American put options.

<u>Option Open Interest and Pricing</u>

There is a significant body of research that has discussed the implications of price discovery provided by derivative markets. For the context of this paper, I will focus on the price discovery mechanism of equity options on the underlying stock they represent. I look at the pricing effect of both the price of an equity option as well as the information provided by the level of open interest in that specific contract. The literature I discuss below provides the rationale for using these inputs to forecast the expected price of the underlying option and thus its future volatility.

Manaster and Rendleman (1982) used the Black-Scholes Model to determine the future price of a stock given an observed option price. The Black-Scholes Model has five variables, strike price, underlying price, risk free rate, the instantaneous variance of the stock and the time to maturity. The Black-Scholes Model can be reworked using a known, and currently observable, option price as well as other known market inputs for the risk free rate, volatility of the underlying stock, time to maturity and the strike price of an option to find the future value for the stock, based on the price of the call option today. "Hence, if options are actually priced according to the model, implied stock prices will be the option market's assessment of equilibrium stock values" (Manaster and Rendleman, 1982, p. 1043).

Easley, O'Hara and Srinivas (1998) write a piece that discusses where informed traders choose to trade, and what effect options transactions have on stock price. Importantly the trio clarifies how an equity option can provide price discovery for the security it is derived from. The authors argue that "an option is a derivative security so its price should be dictated unilaterally by the behavior of the stock price. This unidirectional linkage is only true, however, in complete markets; if information is impounded into prices by trading, then the ability of informed traders to transact in options markets means that the option trading process is not redundant" (Easley, Hara & Srinivas, 1998, p. 431).

Finding that option prices are not redundant, and therefore add pricing information to the underlying stock refutes the idea postulated by Black and Scholes that an investor can replicate any option with some combination of the underlying stock and the risk-free rate. Easley et al. (1998) go on to conclude that there is some level of price discovery provided by informed options traders. The research shows a link between negative options trading volume and negative price moves in the underlying stock, and vice versa with positive options volume (Easley et al., 1998).

Schlag and Stoll (2004) discuss the price impacts of options and futures volume on the German DAX index. The two found that the net level of options puts provided a contemporaneous effect on the future index price, an increase in net calls led to an increase in the DAX and an increase in net puts was shown to lead to a negative pricing effect on the index. "A net purchase of 1,000 call contracts results in an immediate price increase of 3.13 index points. Similarly, a net purchase of puts has a significant negative contemporaneous effect with a coefficient at lag 0 of -2.83" (Schlag & Stoll, 2004, p. 78). The study concludes that both futures and options volumes have an impact on the future price of the DAX index, although they do find that futures trades have a more lasting effect on the index than options trades.

Pan and Poteshman (2006) write an article that uses the changes in open interest to calculate put-call ratios for the security. They find that stocks with bearish put-call ratios will tend to have negative returns in the next period. Conversely, stocks with positive put call ratios will experience positive stock moves in subsequent periods. For their study they considered positive put call ratios to be those in the upper quintile, while those in the lowest quintile were considered to have a negative put call ratio. The two find "predictability that is strong in both magnitude and statistical significance. For our 1990 through 2001 sample period, stocks with positive option signals outperform those with negative option signals by more than 40 basis points per day and 1 percent per week on a risk-adjusted basis (Pan and Poteshman, 2006, p.

872)." They also showed that the signals provided by the put call ratios, and implicitly open interest, get incorporated into the underlying assets price over time.

Option Pricing Prior to Earnings Announcements

Patell and Wolfson's (1979) work on the informational role of the option market when determining the future variability of an asset leading up to an earnings announcement was highly influential to this article. The method used was meant to be as simple a model as possible where investors expect the time leading up to an earnings release to be a high volatility period. This results in options that are priced at a temporarily high level due to the greater anticipated volatility assumptions. The result is options that are priced according to the increased volatility assumptions, leading to a higher premium than would otherwise be expected. "The Black Scholes (1973) option pricing model enables us to infer from option prices the expected stock price variability at dates surrounding the earnings announcement. A time series of option prices can reveal the anticipated increased security price variability even if, ex post, the announced signal has little or no effect on stock price" (Patell & Wolfson, 1979, p. 118).

In their initial study, Patell and Wolfson (1979) used stock and option data collected from the *Wall Street Journal* which they felt were incomplete and added an upward bias to the results. The two decided to re-evaluate their results two years later using the much more complete Berkeley Options Database, which is "a nearly complete record of transactions data covering the 14-month period from August 23, 1976 through October 21, 1977" (Patell & Wolfson, 1981, p. 435). It was thought that by using better data they would be able to reduce some of the bias in the first study due to the large increase in observations available to them, specifically from intraday options prices.

In their second, more robust, study Patell and Wolfson (1981) found that there was a significant increase in options volatility leading up to an earnings announcement. They also noted that just before the announcement, implied volatility increases. Immediately following the announcement, volatility will begin to normalize back to average levels. They also discovered that the increase in implied volatility leading up to the event and the following normalization effect was strongest for shorter termed options.

In 1982 Cheung and Whaley decided to test the efficiency of the CBOE options market by looking at the informational role provided by price movements of options leading up to an earnings announcement. Ultimately earnings drive the value of a stock, which is why unanticipated earnings, positive or negative, will have a corresponding effect on stock prices. Patel and Wolfson are "able to support an information-content hypothesis, which posits that a firm's quarterly earnings announcement affects the standard deviation of the stock return distribution, [however] they are unable to make a statement about the efficiency of the CBOE" (Cheung & Whaley, 1982, p. 58). For Cheung and Whaley, the object is to make an explicit statement about the efficiency of the CBOE. In the end, the pair found that the CBOE is an efficient market. In other words a trader cannot make a net profit after transactions costs if trading based on earnings announcements.

It is options investors who write option contracts and as a result, option open interest is endogenous. The act of writing options and creating open interest allows for the possibility that investors are bringing private information to the market implied by the prices at which they are willing to buy or write options. Interestingly, Schachter (1998) finds that "open interest is significantly below normal for several days prior to the earnings announcement date and is indistinguishable from normal, from the announcement date through the end of the report period"

(Schachter, 1988, p. 369). This finding is in contrast to other studies that find open interest rises leading up to an earnings announcement, such as the study by Lee and Amin that find option open interest increases by roughly 10 percent in the four days leading up to an earnings announcement ("Option Trading," 1994).

In 1993 Li-Chin looked at the difference in companies with and without options and how their stock price changed in relation to earnings releases. She discovered that "the surprise associated with quarterly earnings announcements is greater for nonoption firms than for option firms, and that the security prices of option firms anticipate annual accounting earnings changes earlier than those of nonoption firms" (Li-Chin, 1993, p. 383). This is important because it shows the role of options in price discovery. The role that options markets play in reflecting a company's accounting earnings in their stock price is important because it helps to improve the efficiency of the market leading up to and during these events.

Assuming that investors will only go long option contracts in order to achieve the desired exposure, Donders, Kouwenberg and Vorst (2001) show evidence that supports the notion that trading and open interest in options contracts increase leading up to an earnings announcement and subsequently revert back to normal after the event. This finding is the opposite notion that Schachter (1988) found in his earlier study, where open interest decreased prior to an earnings announcement. However, the Donders et al., (2001) study uses data from the AEX Options Exchange (Amsterdam), which the authors contend has more private investors, leading to longer time to process and greater over reactions to new information, than the Anglo-Saxon markets.

Importantly, Donders et al. (2001) show that the implied volatility in options, both calls and puts, increases more quickly than would be justified using realized volatility in the days prior to the announcement. The group (Donders et al., 2001) also found that changes in open interest and volume indicate that traders are initiating long straddle positions (buy a put and a call), essentially placing volatility bets on the underlying stock. This is the first mention in the literature of using the straddle option strategy to enter a speculative volatility position, which will be an important part of this paper.

<u>Short Dated Options</u>

An option that is at-the-money, with little time left to expiration should be worth practically nothing, assuming no upcoming high volatility events occur (Black & Scholes 1973). However Patell and Wolfson (1979, 1981) show that at-the-money options that expire shortly after a volatility inducing event, do indeed trade for non-arbitrary values. As a result of this fact short-term options have often been excluded from academic studies, for example the work conducted by Manaster and Rendleman (1982). For the purpose of this study, short-dated options are those that are the next options to expire, typically with less than 45 days to expiration.

In a recent article by Billings and Jennings (2011), the two specifically chose to study short-dated options because of "their ability to supply a measure of traders' allowance for upcoming information content. In particular, we hypothesize that short dated options derive their market value from traders' forecasting firm- and quarter specific, earnings-induced increases in stock price volatility. In other words, we predict that soon-to-expire, at-the-money options become valuable when traders believe that an upcoming earnings announcement will elicit a stock market reaction" (Billings and Jennings, 2011, p. 588). In simple terms, the two are expecting the price of a short term at-the-money option to experience an increase in implied volatility, leading to an increase in the option value.

This change in the implied volatility of the option is to allow for the traders' expectations of the anticipated reaction of the stock market to the dissemination of earnings news. Or said in another way, the changing implied volatility is the option traders estimate of how large a price change there will be on the stock, given the earnings release. As mentioned above, short-dated options should be worth almost zero, absent an event that is expected to cause an increase in volatility. This characteristic makes them a very good choice to examine volatility expectations of the market related to earnings releases (Billings and Jennings, 2011).

The research referenced in this study was focused on three topics: the theoretical value of options, how options open interest can forecast future price changes, and a brief discussion of the characteristics of short-dated options. I chose to review the work in these three topics because of the value they will provide to the topic at hand. I this paper I discuss a very similar concept: short-dated options reflecting expectations for the absolute price change of an underlying stock with an upcoming biotech approval date. Specifically, I examine the accuracy of the estimated future absolute price change of a small cap biotech stock facing a known FDA announcement.

The hypothesis of this paper is that informed options traders are adding a risk premium to the options price equal to the expected heightened implied volatility of an underlying stock, and thus a short term option, leading up to an FDA event date. This proposition will be tested by creating a simple, long straddle position using at-the money options for more than 100 individual small cap biotechnology company events. The events are advisory committee meetings and PDUFA approval/denial dates, and the data was gathered using The FactSet options database.

As Black (1973) points out the value of at-the-money short-term options using the Black-Sholes Model is practically zero. Therefore, if the options are trading at a positive value, it is a result of the event risk premium. The predictive capacity of the event risk premium, predictive of the absolute price change of the underlying stock based on the result of an event, could be used by traders and hedgers to manage expectations for price movement of the underlying stock leading up to an FDA event date. The addition to the literature is similar to the research done by Donders et al., (2001), where the group found that traders were initiating long volatility positions for stocks approaching an earnings announcement. Whereas this study focuses on biotech stocks leading up to FDA event dates.

CHAPTER III

METHODOLOGY

Thesis Methodology

As referenced in Donders et. al., (2001) an investor can create a long volatility position by buying a put and a call option, also known as a long straddle. This paper will use the price of one long straddle and the strike price of the near month at-the-money options to estimate a lower and upper price target for the underlying stock. The price of the long straddle plus and minus the strike price of the at-the-money options should roughly indicate the expected absolute price change after an event, as well as the implied volatility of the underlying stock that is approaching this type of high volatility event.

This information is useful to anyone who has or wants exposure to the underlying company. Those people who have a long equity position in the company, for any reason, may wish to limit the uncertainty of the future event, are referred to as hedgers. Someone who wishes to gain exposure to a market, particularly using leverage, is termed a speculator in this paper. Both of these types of investors can benefit from the accuracy of price and volatility estimates provided by options markets. An arbitrageur could use a volatility position similar to the one in this paper to potentially make a riskless profit by either buying or selling straddles.

To determine the accuracy of the model's estimates, I will compare the estimated T_{-3} price to the actual price of the underlying stock at T_{+1}. The smaller the difference in price the better the prediction of price volatility provided by informed investors in the market. I plan to use descriptive statistics to measure the accuracy of the upper and lower price targets associated with these high volatility events. Once the upper and lower bounds are estimated, the accuracy of the predictions can be determined one day after the event date by using the upper bound price as a comparison when the actual price ends up above the strike price and vice versa for below the strike price. Finally, a t-test is used to determine if the deviation between the estimated price and the actual price is significantly different from zero.

If the result of this comparison does deviate from zero, either up or down, it may indicate the ability to use either a short or long straddle position to profit from the mispricing in the underlying stock associated with this type of high volatility event. Depending on the degree of variation, I can determine if there is the potential for monetary advantage by using the information provided by informed options investors leading up to FDA event dates in small cap biotech stocks.

I also conduct a secondary analysis using a multiple regression model to determine the effect of put and call option open interest on the price of the underlying asset one day after the event occurs (T_{+1}), using the option data from three days prior to the event (T_{-3}). The multiple regression model is appropriate because it tests how a number of independent variables affect a dependent variable. In this case the independent variables will be the open interest of the call option and the open interest of the put option. My null hypothesis states that these two independent variables will help predict the dependent variable, the absolute price change of the underlying stock that is seen on the day after the result is announced.

I include the open interest as a measure of liquidity of the option market on the underlying stock, presumably the larger the open interest the more informed investors there are providing pricing information regarding the upcoming event. As a result, increased open interest in long straddle positions should lead to more accurate estimates of price change for the underlying stock. Significantly increased accuracy would lead to increased relevancy to hedgers and speculators.

Data

The study looks at how the price and open interest of a long straddle position using short term, at-the-money options can help predict future stock volatility, based on an upcoming PDUFA action date or an FDA ADCOM date. I obtained the options data used in this study from FactSet's Option Database. General stock information such as price and market capitalization was also provided by FactSet. I also used publically available data to compile a list of the above mentioned event dates. These events were sourced primarily through company press reports and 10Q and K reports. I was also able to find a relatively small group of investors, and one government agency, that provide similar data for free on the internet. The websites I found most useful for this research paper were FDATracker.com; Biopharmcatalyst.com and Clinicaltrials.gov.

These services were good data aggregators which helped to identify small cap biotech companies that have attempted to bring new therapies to market. The time period of my investigation is December 2007 to April 15, 2013. I do not claim that the list is all inclusive of the events in this time frame, but I believe it is a good representation of the events during this time period. In order to be considered for this study, I only used events for which specific guidance was available regarding the timing of the event prior to the actual event date. Adam Feuerstein is a Senior Columnist with *TheStreet* who writes many articles on the subject of biotech event dates. Many of his articles include specific upcoming FDA event dates. His articles are available online for those who are interested. The event dates provided in his articles were a valuable source of information for this research paper.

Specifically, I looked for Biotech companies that were facing an ADCOM or PDUFA action date events. I tried to find forward-looking, publically available information to limit look back bias. I did this by using information that was available prior to the actual event date to find and determine the timing of the events I used in this study. For example at the beginning of 2008 I looked for information regarding upcoming events during 2008 and into 2009, events that were publically disclosed and available to anyone with an interest.

I chose to use "look-ahead" information on event dates in order to avoid any other biases that may have been introduced by using data from companies that provided unanticipated dissemination of event news. Unanticipated news dissemination may not allow informed investors to react to event dates in the same way as when the date is publically disclosed ahead of time. Furthermore, it is my expectation that increased publicity about these events will also help increase the liquidity of the options markets leading up to the event date, which should help narrow Bid-Ask spreads and increase open interest. An increase in put and call option liquidity is also anticipated to enhance the accuracy of the price estimate of the stock at T_{+1}. The enhanced accuracy is a result of the additional pricing information provided by a larger number of options traders.

Using a list of more than 200 identified events, I first determined which companies had a market for options at the time of the anticipated event. Once the companies with options markets were determined I began removing the data points where the associated company had a market capitalization larger than $4 billion. I did this because companies larger than this are more likely to have a previously approved drug on the market, resulting in a source of stable cash flow. A reliable source of cash flow for a biotechnology company will reduce the associated price volatility of the underlying stock on an event date.

After removing companies that exceeded the market cap limit, I was left with roughly 160 companies that fit the requirements for the study. From this point, I verified that the event actually took place using data provided by FactSet. In some cases, I was unable to find evidence that the anticipated event ever actually occurred, and in that case I excluded it from the sample for this study. I left an event in the sample if I could confirm it met one of three criteria: (1) the event outcome was an approval, (2) the event outcome was a failure (i.e., a Complete Response Letter from the FDA, or a negative ADCOM committee vote), or (3) the outcome of the event was delayed. Even if the outcome is delayed investors will still have initiated their long-volatility positions prior to the delay being known and as a result we can still look at the expected volatility of the underlying stock leading up to the event date. The possibility of a delay is a risk for the long in this position, and must be considered when initiating a position.

In order to establish a volatility position, I used the end of day (EOD) put and call option trade prices, as provided by FactSet. I am interested in looking at the predictive power of these volatility positions using the option prices and open interest at T_{-3} to predict the future price at T_{+1}. T_0 will be the actual date the FDA event occurred, for each underlying company. In some cases two companies may be collaborating on the same therapy, and if both companies fit the above outlined parameters both would be included in the dataset.

The primary purpose of this study is to estimate the accuracy of the target prices developed from the options price at T_{-3}. The appropriate estimated target price is compared to the actual price at T_{+1} to determine the accuracy and significance of the predictions. The null hypothesis is that the premiums charged for going long one at-the-money call and one at-the-money put option 3 days before the event will be roughly equal to the absolute price movement of the underlying stock, experienced 1 day after the binary event date. The alternative hypothesis is that the price of the volatility position will not be equal to the absolute percentage change in the underlying stock after the binary event date.

I also use the open interest of both the put and call options to help determine the incremental predictive capability of the liquidity of the options securities markets. The open interest is important for two reasons. First the open interest will help to show how many "informed investors" are initiating volatility positions leading up to these event dates. And the second reason is that, presumably, the more informed investors bringing new information to the market, the more accurate the volatility predictions will be. I used the EOD open interest of the underlying provided from the FactSet database I have previously referenced.

I used a multiple regression model that states call and put option open interest at T_{-3} help predict the absolute price movement reflected in the underlying asset.

Null Hypothesis:

H_0: $E(P_{U\,t\text{-}3})$ or $E(P_{L\,t\text{-}3}) - P_{T+1} = 0$

H_a: $E(P_{U\,t\text{-}3})$ or $E(P_{L\,t\text{-}3}) - P_{T+1} \neq 0$

Where: $E(P_{U\,t\text{-}3})$ or $E(P_{L\,t\text{-}3}) - P_{T+1}$ = The difference between $P_{(T\text{-}3)} - P_{(T+1)}$
$E(P_{U\,t\text{-}3})$ = The estimated upper Price Target – using options data from T_{-3}.
$E(P_{L\,t\text{-}3})$ = The estimated lower Price Target – using options data from T_{-3}.
P_{T+1} = Actual price at T_{+1}.
e = Error of the model

Secondary Research Question:

Regression Equation:

$\hat{Y} = a + \beta X_1 + \beta X_2 + e$

Where: $\hat{Y}$ = The difference between $P_{(T\text{-}3)} - P_{(T+1)}$
a = The y-intercept
βX_1 = Open interest in put
βX_2 = Open interest in call
e = Error of the model

Possible Results

In order to determine whether the estimated price change provided by the price of the straddle is accurate, I compared the T_{-3} options price estimates for the underlying stock at T_{+1} to the actual underlying stock price at T_{+1}. A result that deviated from zero significantly would suggest that the options market is consistently over or under estimating the volatility of this type of event. However, a result that does not significantly deviate from zero would suggest that the options market has accurately estimated the future volatility of the FDA event.

An increase in open interest may be associated with more accurate estimation of the underlying stock price after the FDA event date. This is because as interest and awareness builds surrounding these events hedgers and speculators will seek to transfer risk among one another, causing open interest to rise. Presumably the increased visibility of the company's therapy will bring increased pricing knowledge to options positions providing more accurate estimates of the future price volatility of the underlying stock.

CHAPTER IV

DATA COLLECTION AND PRESENTATION

Discussion of Data Collection and Presentation

To ensure that all of the event dates that I used were publicly available, I only used events that were highlighted on the biotech investment websites, mentioned in Chapter Three, or in company reports. I used publicly available data in order to limit the effect of inside information. I started by creating a list of all the FDA Advisory Committee (ADCOM) and Prescription Drug User Fee Act (PDUFA) action dates that I could find between December 2007 and April 2013. The sample was narrowed to a list of 220 of these events, found exclusively from public sources. I used these two types of events because of the importance of the outcome of these events on the future cash flows of the respective company.

ADCOM meetings are meetings with a group of experts in the field associated with the indication being tested. The meetings are generally set up by the FDA to gather industry feedback about the therapy moving through the regulatory process. During these events there is a vote regarding the risk reward trade off of the proposed new drug. Although these votes are not binding, the FDA usually follows the committee's recommendations.

PDUFA dates are the final approval/rejection decision date by the FDA. If rejected, the company will receive a Complete Response Letter (CRL) that discusses the reason the FDA decided not to approve the therapy. The sponsoring company may elect to try to rectify the issue and re-file a New Drug Application (NDA) or it may stop development of the drug if it deems the prospects to be too bleak.

From the initial list of events, I removed all companies with a market cap of greater than $4 billion. I chose to use companies with a market cap of less than 4 billion dollars because the companies under this threshold are most exposed to the binary nature of a pass/fail decision by an ADCOM committee or the FDA. This is because small biotech companies generally have few if any sources of steady cash flow. As a result the dramatic increase or decrease in the probability of future cash flows has a large effect on the stock price of pre-cash flow biotech stocks.

As a company's market cap increases the more likely it is to have other sources of potential and actual cash flow aside from the potential cash flow of the drug undergoing the regulatory process. In short, more sources of cash flow, potential and actual, for a company diminish the volatility associated with any one particular event outcome. I found a total of 179 PDUFA/ADCOM events for companies with a market cap of less than $4 billion. Again, all of these events occurred between August 2007 and April 2013.

Once the list of events was compiled I removed events for which I could not find independent confirmation of the event having taken place. I looked for press releases or other news events that discussed the event in question. Generally there are three potential outcomes for an event in the future. The event may occur, it may not occur or it may be delayed. The same is true for ADCOM and PDUFA dates. The FDA may delay a PDUFA date if it feels that the agency needs more time to make a decision on the therapy. Delays are a risk of this type of investing.

From this point I reduced my list of events to 139 observations. The remaining observations where ADCOM and PDUFA dates that fit the market cap restriction, and that I could find independent confirmation that they either occurred with positive results, occurred with negative results or were delayed. I kept the delayed events in the list to represent the risk associated with delays because investors in general will not be able to tell which PDUFA dates may be delayed. This means that the investing community will still behave the same way leading up to an event even if it ends up being delayed. The delay may cause a significant loss on the position which needs to be accounted for in order to accurately reflect the true profit potential of this type of position.

I used the FactSet option database to retrieve call and put option data for each event remaining on my list. I chose to use the contract that expired closest to the event date, but not prior to it. Once I had chosen the contract month I looked for the contract strike price that was closest to at-the-money three days prior to the event date. Unfortunately, there were multiple instances where the data was unavailable for various reasons. One reason some data was not available was that I could not download it from FactSet's database. Another reason was stock splits. Rather than making adjustments for stock splits I removed all instances where the stock underwent a stock split causing the options to be adjusted after issuance. Once I removed the observations were I could not retrieve the data, or the data was inconsistent, I was finally left with 112 events that were usable for this regression analysis.

From this point I began to move the data into a usable form for SPSS. Once I had the final list of events I ran several pre analysis data screening tests. The first test was to detect any missing variables. I had no events with missing variables once I began SPSS testing because events with missing data were dropped from my list prior to this point. I then ran a test for outliers. I found 23 distinct total outliers in the data set. There were six outliers in each of the call and put price data for T_{-3}. The call and put open interest for T_{-3} had eight and nine outliers respectively.

I chose to keep these outliers in the dataset because the relative frequency of outlier events (more than 20 percent). The supposed outlier events are important to this study because they show the large profit and loss potential of this position, although infrequent large losses or gains did occur. As a result of this I decided that they were not actually outliers and should be left in the study. Furthermore, the 17 outliers resulting from increased open interest should be helpful for the predictive power of the model. Increased open interest implies that there are more participants in the market, each of them bringing private information to the market and improving the pricing mechanism.

I then normalized the data for my prediction of the absolute price change by looking at the percentage error rather than the absolute error between the estimated target price and the actual price at T_{+1}. It was important to normalize the data because without it the results could be misleading due to the different prices each stock trades at. The normalization process allows me the use of descriptive statistics on the resulting percent error of the estimate. The table below shows the sample statistics for the "percent difference from estimate" variable. The mean error from the estimate is -12.32 percent, which means that the price change predicted by the cost of one long straddle overestimates future volatility by just over 12 percent. The data also show a rather large standard deviation of roughly 37.5 percent. Such a large standard deviation means that a positive 0.3 sigma event would lead to a profit on the long straddle position.

Table 1

One Sample Statistics

This table shows the sample statistics for the variable Percent Difference from Estimate.

	N	Mean	Standard Deviation	Standard Error Mean
Percent Difference from Estimate	112	-12.3271%	37.48489%	3.54199%

For the secondary hypothesis, that more open interest will increase the accuracy of the estimated price target, I used a multiple regression model. The linear regression model has several assumptions that must be met in order to realize accurate results. The assumptions of the linear regression model include the assumption of normality, which assumes that the error terms are normally distributed. The model also requires a linear relationship between the Y (dependent) and X (independent) variables. Also, the multiple regression model assumes that there is no multicollinearity between the X variables. The model also assumes the expected value of the error term is zero. The variance of the error term is expected to be constant. And finally the error terms cannot be serially correlated.

I chose to use a multiple regression model for the secondary thesis of this study because it shows the effect of each independent variable on the dependent variable. The model is developed by using at least one independent variable to estimate the value of just one dependent variable. For my model the independent variables used were the call open interest at T_{-3} and the put option open interest at T_{-3}, to determine the effect of option open interest on the actual price of the stock at T_{+1}.

CHAPTER V

DATA ANALYSIS

Descriptive Statistics – Primary Hypothesis

The test for accuracy of the predicted price targets is performed using the descriptive statistics of the sample data. The hypothesis for the primary research question is whether or not the options trading on a small cap biotech stock can help predict the future absolute price change of the underlying stock once the predetermined FDA event occurs. The future absolute price change is estimated using the price to buy one long volatility position. The price of the volatility position is then used to find the upper and lower breakeven prices of the underlying stock as options traders estimate the future stock price, given a positive or negative event outcome.

This type of study uses data that is taken from many different companies undergoing a similar approval process, rather than one company going through the same process many times. As a result, I attempt to determine the effect of the FDA event on a company's share price based on the outcome of the event - not necessarily the company's potential or intrinsic worth or the specific therapy's potential. There are instances of a company going through the regulatory process multiple times with the same therapy. These instances are included in the data set once for each unique application process. This is generally the result of receiving a Complete Response Letter in a prior application process.

The underlying companies all have different characteristics such as market capitalization, institutional ownership, analyst coverage and the size of the market for the specific therapy. These differences mean that each company will trade uniquely based on its particular circumstances. As a result I use the percentage error rather than the absolute error between the estimated price target and the actual price for this study. In addition, the descriptive statistics of the prices of the put and call options may not be valuable information in isolation. This is because the price of the underlying stock can have a large effect on the price of the options, as well as the other common option variables such as, interest rates, time to expiration, implied volatility etc., all of which are an essential part of most standard options pricing models. The effect of time value appears limited until after the FDA event occurs. At which point both implied volatility and theta value begin to return to a more normalized level, draining significant value from both put and call options.

The statistics I outline below are only descriptive of this set of sample companies. The descriptive statistics would likely change significantly with a different sample of companies undergoing a similar regulatory process. Table 2 shows the descriptive statistics for the error of the estimate and the actual price of the stock at T_{+1}. The percent difference from the estimate variable shows the accuracy of the estimated price targets. In order to compare the difference in price for the various stocks in the estimate the percentage difference is used as the variable instead of the absolute difference.

Table 2 shows that the options markets estimated target price is, on average, over estimated by 12.3 percent This is shown by the mean of -12.32 percent. By itself the mean error of the estimate is misleading. The table shows that the models largest overestimate of a price target was 286 percent, whereas the largest underestimate of a price target is 77 percent, leaving a range of more than 325 percent. The distribution has a skewness of -3.54, which means that this model consistently overestimates volatility and also has more extreme overestimates than underestimates. The kurtosis of the distribution is 25.756 meaning that although there is a very large range for the data, most of the observations fall relatively close to the mean observation of -12.3 percent.

The mean price for the stocks just after the event date at T_{+1} is $13.73, while the median is $10.37, which is an indicator that the stock price data is positively skewed because the mean is further to the right tail than the median. Interestingly the distribution for the stock price at T_{+1} is closer to a normal distribution than the 'percent difference from estimate' variable. However, this distribution better depicts a lognormal distribution than a normal distribution, which is shown in Table 1 by the kurtosis of 3.74 and the skewness of 1.83. A normal distribution has a kurtosis of 3 and a skewness of 0. The skewness shows that the probability distribution has more positive values than negative, which intuitively makes sense because a stock price cannot be negative.

Table 3 shows the results of the t-test for the percent difference from estimate variable. The t-value is -3.48, which is highly significant even at an alpha .001. According to the t-test the difference between the expected price and the actual price is statistically significantly different from zero. This result confirms that the difference between the estimated price targets, using the combined premiums of one at-the-money call and one at-the-money put, and the actual future price is not equal to zero.

Table 2

Descriptive Statistics

This table shows the descriptive statistics of the variables Percent Difference from Estimate and Actual Price at T+1.

	Percent Difference from Estimate	Actual Price T-1
N	112	112
Mean	-12.3271%	13.732143
Standard Error of the Mean	3.542%	1.1161086
Median	-9.6649%	10.365
Mode	-286.24%	0.92
Standard Deviation	37.48489%	11.8117834
Variance	1405.117	139.518
Skewness	-3.54	1.831
Standard Error of Skewness	0.228	0.228
Kurtosis	25.756	3.744
Standard Error of Kurtosis	0.453	0.453
Range	363.82%	59.02
Minimum	-286.24%	0.92
Maximum	77.58%	59.94

Table 3

One Sample T-Test

This table shows the T-Test of the variable Percent Difference from Estimate.

					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Percent Difference from Estimate	-3.48	111	0.001	-12.3271%	-19.3458%	-5.3084%

Inferential Statistics – Secondary Hypothesis

The inferential statistics of the study are confined to the secondary hypothesis. I use a multiple regression model to determine if put and call option open interest is helpful to increase the predictability of stock price at $T_{+1.}$ Option open interest from T_{-3} is used to try to predict the absolute price movement one day after the event occurs. The call and put open interest can be affected by many outside influences beyond proximity to an FDA event date, which limits the value of the descriptive statistics for this part of the study.

In this part of the study I examine the value of using a set of known parameters to try to predict the absolute price change of the underlying stock after the event has occurred. This can be achieved because we are looking at what we expect to happen, using option information that is already known and available through options exchanges and brokers.

Table 4 shows the correlation of the variables to one another. The put option price had a positive correlation to the stock price at T_{+1}. This result is more confusing because if an investor is willing to pay more for a put, it could be surmised that it is because the stock price is moving into, or deeper into, the money for that particular put option. This would mean the price of the underlying stock is falling. This should lead to a negative correlation between price at T_{+1} and the put option price, but instead the data shows a statistically significant positive correlation of 0.512. The positive correlation shows that as the price increases, people are willing to pay more for the put option. This is likely because market participants expect the price to fall further now that the price has risen, known as increasing implied volatility.

There is a statistically significant positive correlation between the call price and the stock price. This result is what I would expect because as the stock price increases the call option is going into, or deeper into, the money. The further in-the-money the call option is, the more intrinsic value it will have resulting in a higher price for the security. The correlation between stock price and call price is 0.541 as seen in Table 4. This is similar to the correlation between put option price and stock price.

The last correlation I discuss is the correlation between put open interest and call open interest. Table 4 shows that there is a statistically significant positive correlation between the two open interests of 0.311. This shows that some people open call positions because they think the price will increase. But there are also investors who think that the price is likely to fall, and as a result they begin to open put positions on the stock. The correlation between the open interests suggests that for approximately every three new contracts of call open interest, there will be one new contract of put open interest in the equivalent put options.

The Model Summary in Table 5 shows the R, R^2 and the Adjusted R^2 at -0.014. This implies that the two independent variables are not useful when predicting the future absolute change in stock price of the underlying at T_{+1}. The Adjusted R^2 is the most relevant to look at because it is adjusted for the number of independent variables in the model. Without adjusting for the number of independent variables, an increase in the independent variables will cause a corresponding increase in R^2. R^2 is typically seen as a "goodness of fit" for the linear regression line relative to the models data.

Table 6 focuses on the independent variables of the regression model. This table contains the beta coefficients for each of the variables as well as the standard errors of those betas. The betas are important because they are the constants in the regression model equation. The table also shows the result of the T-test for each independent variable and the significance level of the variable as determined by the corresponding T-test. This information is important because it is used to determine which independent variables are significant in predicting the value of the dependent variable, stock price at T_{+1}. The "sig." variable shows that neither the put nor call open interests are significant at the 95 percent level. The table also roughly shows at what alpha each independent variable becomes statistically significant.

Finally, Table 7 refers to the Analysis of Variance of this multiple regression model. Despite the name, the analysis of variance or ANOVA test is used to test for significant differences between means. When developing a linear regression model the variance in the estimate is a result of both the error in the regression model and any residual error. The residual error is the variance that is not explained by the model. The ANOVA test also shows the overall significance of the model via the F-Test. The F-value of the model is not greater than the critical F-value meaning the model is not considered significant at the 95 percent confidence level.

Table 4

Correlations 2-tail

This table shows the Pearson Correlations of the variable used in the primary and secondary research questions.

Correlations 2-tail	Actual Price at T_{+1}	Percent Difference from Estimate	Call Open Interest	Put Open Interest	Call Price at T_{-1}	Put Price at T_{-1}
Actual Price at T_{+1}	1					
Sig. (2-Tailed)	-					
Percent Difference from Estimate	0.1	1				
Sig. (2-Tailed)	0.294	-				
Call Open Interest	0.169	0.043	1			
Sig. (2-Tailed)	0.075	0.651	-			
Put Open Interest	-0.054	0.064	0.311	1		
Sig. (2-Tailed)	0.57	0.505	0.001	-		
Call Price at T_{-1}	0.541	0.083	0.083	0.01	1	
Sig. (2-Tailed)	0	0.384	0.383	0.914	-	
Put Price at T_{-1}	0.512	0.126	0.157	0.012	0.711	1
Sig. (2-Tailed)	0	0.185	0.099	0.9	0	-

Table 5

Regression Model Summary

This table shows the Regression Model summary for secondary research question.

	R	R Square	Adjusted R Square	Standard Error of the Estimate
Model 1	0.068	0.005	-0.014	37.73911%

Table 6

Regression Model Coefficients

This table shows the Regression Model coefficients for secondary research question.

	Unstandardized Coefficients		Standardized Coefficients		
	B	Standard Error	Beta	t	Sig.
(Constant)	-14.354	4.74	-	-3.028	0.003
Call Open Interest	0.000	0.001	0.026	0.258	0.797
Put Open Interest	0.001	0.001	0.056	0.552	0.582

Table 7

ANOVA

This table shows the Regression Model Analysis of Variance for secondary research question.

	Sum of Squares	df	Mean Square	F	Sig.
Regression	725.753	2	362.876	0.255	0.776
Residual	155242.194	109	424.24	-	-
Total	155967.947	111	-	-	-

CHAPTER VI

DISCUSSION, CONCLUSSION AND RECOMMENDATIONS

Discussion

The primary purpose of this study is to determine whether or not the price of a long at-the-money straddle accurately estimates the future upper and lower price targets of the underlying stock while approaching an FDA event. Does the estimated price of the underlying stock, using option prices from T_{-3}, equal the actual price of the underlying stock at T_{+1}? The estimated price targets, as determined by options traders, have overestimated volatility if the actual price at T_{+1} is between the upper and lower price targets that are established using the T_{-3} option data. Conversely, options traders have underestimated volatility if the actual price is beyond the upper *or* lower estimated price targets. As mentioned in Chapter 5, the study looks at the percent deviation from the appropriate price target rather than the dollar deviation from the price target. If the stock at T_{+1} is above the strike price of the at-the-money strangle, then the upper price target is used as the target price and vice versa if the actual price is below the strike price.

Referring to Table 2 (Chapter 5), the mean percentage difference from the price target is -12.32 percent. The t-test for the variable is shown in table 3 (Chapter 5). The t-test determines whether the percent difference from the estimate is statistically significantly different from zero at the 95 percent confidence level, which it is. The t-test for this variable is -3.48, which is significant at the 99.9 percent confidence level. This indicates the near certainty that the expected target prices before an event do not reflect the actual price after the event occurs. As the descriptive statistics in Table 2 show, the implied volatility is greater than the expected volatility in nearly 80 percent of FDA events in this sample. Therefore, for instances where the actual price was above the strike price the actual stock price, on average, was 12.32 percent lower than the estimated price. When the actual stock price was below the strike price then the stock price was, on average, 12.32 percent higher than the estimated price. In both situations the long straddle position overestimated the volatility of the stock when compared to the actually volatility that occurred one day after the FDA event.

The skewness of -3.54 indicates that the long straddle position almost always overestimates the future price changes of these events. In only 24 out of 112 total observations, or 21.4 percent, did the long volatility position underestimate the future absolute price change of the underlying stock. This implies that a short straddle position initiated three days before an FDA event date and closed one day after the event date would return, on average, roughly 12 percent in four days. This is information could be very useful to the various traders and investors.

The secondary research question is whether an increase in put and call open interest at T_{-3} helps explain the change in price at T_{+1}. The secondary research question is modeled using multiple regression. The model uses two independent variables, call and put option open interest, to determine the effect of open interest on absolute stock price change four days in the future. The results show that the two independent variables above are not statistically significant indicators of the underlying stock's absolute price change one day after an FDA event date. At-the-money option open interest three days before an event date does not have a significant effect on the price one day after an FDA event date.

Table 4 (Chapter 5) shows the correlations of the variables. It is interesting that put and call open interest did not have a strong correlation with the stock price at T_{+1}. I expected that as open interest increased, the accuracy of the estimated absolute future price change would improve. Resulting in a stronger correlation with the future stock price. However, the correlations show that neither put nor call open interest at T_{-3} are strongly correlated with the stock price at T_{+1}. As expected, the call option open interest showed a positive correlation to the stock price.

The adjusted R^2 of the model is an important statistic when determining the ability of the model and data to predict the actual outcome, in this case the actual price at T_{+1}. This model has an adjusted R^2 of -0.014, which indicates that put and call option open interest at T_{-3} does not explain any of the changes in the stock price at T_{+1}.

Finally, the model did not exhibit statistical significance, tested at the 95 percent confidence level. As shown in table 7 (Chapter 5) the model exhibited an F-Value of 0.255, which is well below the required F-Stat of approximately 2.4. Such a small F-Value indicates that the model would only be significant below the 77 percent confidence level. This means that put and call open interest is not very significant in predicting the future absolute price change of the stock at T_{+1}.

The low degree of significance of the model and the negative adjusted R^2 show that this model is not useful for predicting the future price of the underlying stock at T_{+1}. This result may differ if more independent variables were included in the model. In the Recommendations for Further Research section later in this chapter I discuss other independent variables that I think may increase the adjusted R^2 of the model.

The final equation for the model is shown below:

$\hat{Y} = -14.35 + 0.00X_1 + 0.001X_2 + e$

Where: $\hat{Y}$ = The Price of the underlying stock one day after FDA event or $P_{(T+1)}$
a = The y-intercept
βX_1 = Open interest in put
βX_2 = Open interest in call
e = Error of the model

I believe that I am the first to study how options information can be used to predict the future absolute price change in a small cap biotech stock leading up to an FDA event date. However, several researchers have done studies to determine the effect of options on stocks that are approaching an earnings announcement. For example, Patell and Wolfson (1979, 1981) found that there was an apparent increase in implied volatility in options leading up to earnings announcements, even if after the fact very little volatility actually materialized. The same effect can be seen in the data for this study. Despite the primary hypothesis not being statistically significant evidence of future price changes. Comparing the estimated price changes to actual price changes shows that the market often over estimates volatility, and rarely underestimates it.

Cheung and Whaley (1982) found that when trading options leading up to an earnings announcement it was not possible to make a net profit after transactions costs. As mentioned in the prior paragraph, the market tends to pay for more volatility than actually materializes. As a result, a trader would very rarely make a net profit after transaction costs by going long one at-the-money straddle position on a small cap biotech stock three days before an event date. A long straddle position consists of one long at-the-money call option and one long at-the-money put option, and both options must use the same strike price.

Conclusion

The practical application of this research is important because these two research questions develop insight into the volatility estimates of the options market leading up to an FDA event. In answer to the primary research question, the model shows that the market overestimates the actual volatility by 12.32 percent, on average, roughly 80 percent of the time. The large degree of error and the consistent nature of the overestimation show that this method of estimating volatility is biased toward greater volatility in the underlying stock.

For the secondary research topic, the models shows that the two easily accessible options variables explain none of the resulting price movement in the underlying stock one day after a high volatility FDA event date. The price targets developed from options data three days before the FDA event date are important information that is valuable to both speculators and hedgers. The ability to estimate price targets for the stock after the outcome of the FDA event would enable speculators and hedgers to better enact their respective trading strategies.

Theoretically, more efficient trading strategies should lead to more efficient markets. As the market approaches equilibrium, speculators, hedgers and investors use their new information for trading purposes. The act of trading on the information provided by options data will cause the incremental knowledge to become priced into the underlying stock. Over some period of time the incremental profit potential from the knowledge will erode, resulting in more efficient markets. Hypothetically, this means that over this sample period shorting volatility would have been a profitable strategy, such a strategy may not continue to be profitable.

This study supports for the notion that short dated options provide pricing information that can be useful for estimating the future price change of an underlying stock. Short dated options were historically seen as near worthless, at least according to the Black-Scholes Model

(1973). However, this study suggests that short dated options have value based on their estimates of future high volatility events as found by Pattell and Wolfson (1979,1981).

Billings and Jennings (2011) used short dated options in their study of volatility associated with earnings announcements to represent an allowance for information content in traders' expectations of volatility leading up to the earnings event date. This study provides corroborating evidence that traders are using short dated at-the-money options to reflect estimates of future volatility, but in this case as a result of upcoming FDA events.

The t-test shows us that we must reject the primary null hypothesis that the expected absolute price target minus the actual stock price at T_{+1} is equal to zero. Interestingly, the high degree of statistical significance implies potential value in selling volatility by going short one at-the money straddle over this time period. Both the put and call open interest proved not to be significant estimators at the 95 percent confidence level. Based on the F-test, the secondary model is not significant, and as a result we must reject the null hypothesis that put and call open interest can help explain the actual stock price one day after an FDA event.

Recommendations for Further Studies

The first area of additional research I would recommend is using call and put option volume, in addition to open interest, to enhance the accuracy of the multiple regression model. This would be useful because it incorporates the actual trading in the options rather than just the outstanding contracts. Volume may be more useful if it is measured based on all call and put options in the option chain for the relevant month. The relative number of puts and calls being purchased may help to enlighten direction instead of just the absolute price change of the underlying stock once the event occurs. Directional information could be extremely useful for traders and hedgers in markets with high volatility, such as the small cap biotech stocks.

For the multiple regression model, time to maturity may be a variable that could be useful in increasing the accuracy of the model. This is because often times the event will take place several weeks before the options expiration, which is when time value decay on options is the greatest and this could have an effect on the option prices. However, leading up to the event date, it appears that time value decay is minimal on these options due to the high expected volatility of the underlying stock. The heightened expected volatility is a result of the binary event forthcoming. The residual time value of the options after the event date may cause the prediction of percentage price change to be biased on the high side unless time value is taken into account.

Another interesting explanatory variable to add to the model might be an estimate of the therapeutic size of the market for the therapy undergoing the regulatory process. Market size of the therapeutic market could help estimate the absolute price change post the event date. This would be an important variable because analysts often use a discounted cash flow model, discounted for the likelihood of approval of the underlying therapy to determine the value of small cap biotech stocks. In these models the cash flows are ultimately derived by estimates of the sales from the new therapy for the company sponsoring the approval process.

The effect may be magnified for the call options because information would generally be used to determine a cash flow level much higher than the company would have if the therapy failed the regulatory process, leading to a higher stock price. An impediment to using this variable would be determining the market size for each therapy. However, if an investigator could achieve relatively accurate size estimates it could be a significant determining factor into the absolute price change of the stock one day after the event date, especially for the upside price target.

One might also add an X variable that could help to define the downside price target of the underlying stock by adding a variable for cash per share of the stock undergoing the regulatory process. In the case of a rejection of the therapy many small cap biotech companies trade near their cash level per share. Cash per share is available on a lagged basis via quarterly reports, which would provide a fairly simple method to determine an approximation of the variable. Using both a therapeutic market estimate and a cash per share estimate the model may predict absolute price changes much more accurately. This information could help traders and hedgers to set target prices more accurately and may ultimately lead to better trading decisions and as a result profit potential.

Finally, it may be beneficial to use lognormal variables in the regression model because the actual distribution of each of the variables more closely represents a lognormal distribution. A variable that cannot have negative values can be modeled better using the lognormal distribution. Ultimately there should be enhanced accuracy of the predictions as a result of modeling the log values of the data.

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APPENDIX

Basic Options Terminology

ADCOM: FDA Advisory committee
Ask Price: The price that a dealer is offering to sell an asset. (Hull, 2012)
At-the-money Option: An option in which the strike price equals the price of the underlying asset. (Hull, 2012)
Bid Price: The price that a dealer is prepared to pay for an asset. (Hull, 2012)
Binary Event: An event that has one of two outcomes, positive or negative.
Black-Scholes-Merton Model: A model for pricing European options on stocks, developed by Fischer Black, Myron Scholes, and Robert Merton. (Hull, 2012)
Call Option: An option to buy an asset at a certain price by a certain date. (Hull, 2012)
***Cash Settlement*:** Procedure for settling a contract in cash rather than by delivering the underlying asset. (Hull, 2012)
Delta: Change in asset price per dollar increase in the underlying asset. (Deriv - Hull)
Delta Hedging: A hedging scheme that is designed to make the price of a portfolio of derivatives insensitive to small changes in the price of the underlying asset. (Hull, 2012)
***Derivative*:** An instrument whose price depends on, or is derived from, the price of another asset. (Hull, 2012)
Exercise Price: The price at which the underlying asset may be bought or sold in an option contract (also called the strike price). (Hull, 2012)
Gamma: Change in Delta per dollar increase in underlying asset. (Hull, 2012)
Greeks: Hedge parameters such as delta, gamma, vega, theta, rho. (Hull, 2012)
Historic Volatility: A volatility measure calculated from historical measurements. (Hull, 2012)
Implied Volatility: Volatility implied from an option price using the Black-Scholes or a similar model. (Hull, 2012)
In-the-Money Option: Either (a) a call option where the asset price is greater than the strike price or (b) a put option where the asset price is less that the strike price. (Hull, 2012)
***Intrinsic Value*:** For a call option, this is the greater of the excess of the asset price over the strike price and zero. For a put option, it is the greater of the excess of the strike price over the asset price and zero. (Hull, 2012)
Jump Process: Stochastic process for a variable involving jumps in the value of the variable.
Liquidity Risk: Risk that it will not be possible to sell a holding of a particular instrument at its theoretical price. (Hull, 2012)
***Market Maker*:** A trader who is willing to quote both bid and offer prices for an asset. (Hull, 2012)
Maturity Date: The end of the life of a [option] contract. (Hull, 2012)
***Open interest*:** The total number of long positions outstanding in an options contract (equals the total number of short positions).

Opening Transaction**:** A transaction in which a trader establishes or increases a position in an option. (Chorafas, 2008)

Option: The right to buy or sell an asset. (Hull, 2012)

Out-of-the-Money Option**:** Either (a) a call option where the asset price is less than the strike price or (b) a put option where the asset price is greater than the strike price. (Hull, 2012)

PDUFA: Prescription Drug User Fee Act

Premium: The price of an option. (Hull, 2012)

Put Option**:** An option to sell an asset for a certain price by a certain date. (Hull, 2012)

Rho: Change in option price per 1 percent increase in the interest rate. (Hull, 2012)

Short Selling: Selling in the market shares that have been borrowed from another investor. (Hull, 2012)

Speculator: An individual who is taking a position in the market. Usually the individual is betting that the price of an asset will go up or down. (Hull, 2012)

Stock: Ownership of a share of the equity of the issuing company.

Stock Option: Option on a Stock. (Hull, 2012)

Strike Price: The price at which the asset may be bought or sold in an option contract (AKA Exercise price). (Hull, 2012)

Theta: Change in option price per calendar day passing. (Hull, 2012)

Theoretical Value: The value of an option using a pricing model, such as Black Scholes or the Cox-Ross model.

Time Value**:** The value of an option arising from the time left to maturity (equals an option's price minus its intrinsic value). (Hull, 2012)

Volatility: A measure of the uncertainty of the return realized on an asset. (Hull, 2012)

Volume**:** The total number of options contracts filled for the day.

Intrinsic Value: The portion of an options value that is a result of the in the money-ness of the option.

Vega: Change in option price per 1 percent change in volatility. (Hull, 2012)

Writing an Option**:** Selling an option (Also known as short the option). (Hull, 2012)