ACRN Journal of Finance and Risk Perspectives
Vol. 1, Issue 2, p. 112-129, Dec. 2012
ISSN 2305-7394

OPTION MARKET OVERREACTION TO STOCK PRICE CHANGES

Eric Gettleman[1], Brandon Julio, Ph.D.[2], Elizabeth A. Risik, Ph.D.[3]

[1] Chesapeake Partners
[2] London Business School
[3] Webster University

Abstract. *In this paper we examine the relationship between implied volatility of individual stocks in the S&P 100 and the ex-post realized volatility of these stocks following weekly movements of at least 10 percent in the underlying stock prices. When conditioning on these extreme stock price events, we find that the implied volatility is significantly higher than the realized volatility. Furthermore, we are able to construct profitable trading strategies based on this finding. These strategies are successful both in event and calendar time.*

Keywords*: Investments, Options, Behavioral Investments, Behavioral Finance, Asset Pricing*

Introduction

"Jefferies shares slumped as much as 20% earlier as traders are jittery about the investment bank's exposure to euro-zone sovereign debt…. Traders are piling into opening put positions…. Jefferies' 30-day implied volatility…has jumped 57% to 142, by far the highest in at least two years." – Wall Street Journal, November 11, 2011 (http://www.wsj.com)

"Rumors that eBay, Inc. could face new competition from Google, Inc. sent investors scurrying to the options market…. Not the kind to wait for confirmation…investors had already focused in on eBay's short-term puts as they weighed what the news could do to the Internet auctioneer's stock. More than twice as many puts traded Tuesday than on an average day in the preceding three weeks." – Wall Street Journal, October 26, 2005 (http://www.wsj.com)

"Even before trading costs are imposed, systematically writing stock options does not appear to generate abnormal gains." – Bollen and Whaley 2004

There is evidence in the literature that investors misreact in the option market. Stein (1989) first documented this misreaction, and more recently, Poteshman (2001) showed that option investors overreact in the long term and underreact in the short term. Anecdotal evidence suggests that investors turn to the option market to act rapidly on pressing information. If that is indeed the case, it seems that there should be a systematic way to generate profits in the option market based on investor behavior. Bollen and Whaley (2004) found that there is no way of systematically obtaining such profits by writing stock options on individual stocks (even before trading costs). Our results stand in contrast to theirs in that we are able to find significant trading profits in writing options. The reason for the difference in results is how we partition the individual stocks. Unconditionally writing puts and calls on stocks, we find results similar to theirs (although on a larger scale – we examine all the individual stocks in the S&P 100 while they look at the 20 stocks with the most actively traded options). When conditioning on recent stock price performance, however, we find that after large stock price drops, the strategy of writing put options systematically provides profits for the investor. Following sharp stock price declines

ACRN Journal of Finance and Risk Perspectives
Vol. 1, Issue 2, p. xxx-yyy, Dec. 2012
ISSN 2305-7394

(of at least 10 percent), there is a statistically significant difference between the implied volatility of options (in particular, out-of-the-money puts) on that stock and the ex-post realized volatility of the stock. Examining short-term out-of-the-money puts, we find that following a five-day stock price drop of at least 10 percent, implied volatility is on average 25 percent higher than the realized volatility on the underlying stock over the remaining life of the option. This large difference leads us to construct two profitable trading strategies, earning returns of between 15 percent and 18 percent over a 30-day period.

Our paper provides two significant contributions to the literature. First, we extend the similar work of Amin, Coval and Seyhun (2004) on index options to individual stocks, providing evidence of overpricing of individual options following movements in the underlying. This overpricing is evidence of investor overreaction to recent information, whereas most prior literature has found option market overreaction only in the long term. Secondly, we create simple trading strategies, which in contrast to much of the existing literature, show that there is a systematic way to profit from writing individual stock options and hedging. One possible exception to this is the work of Goyal and Saretto (2009), who find significant profits from a long-short portfolio of individual options, conditioning on the difference between historical and implied volatilities. There are some significant differences between their work and ours. We condition on an event in the stock market, not the option market, and examine the impact this has on option prices. We restrict our sample to options on the largest 100 firms, rather than all firms meeting liquidity criteria. This likely biases against our finding significant results, as the largest firms with the most liquid securities should be the least likely to show evidence of mispricing. Our strategy also has a better reward-to-risk ratio, with a Sharpe ratio of 1.00 to Goyal and Saretto's 0.73. Our work extends theirs in one interesting way: they suggest that option mispricing may be an overreaction to extreme stock returns—exactly what this paper shows.

While there is no definite explanation of why we find mispricing and are able to profit from it, anecdotal evidence suggests that following sharp price declines unsophisticated investors may panic. In panicking, these investors buy out-of-the-money puts on the stocks they own as insurance, causing the implied volatility of those options to rise, usually to levels higher than the volatility eventually realized by the underlying stock. We implicitly assume limits to arbitrage, which cause demand to have an impact on option prices, as modeled by Garleanu, Pedersen and Poteshman (2009). This allows sophisticated investors to sell out-of-the-money puts on those stocks and delta-hedge, realizing significant profits. This set of events leads us to three testable hypotheses. First, following a sharp price decline, implied volatility should be higher than ex-post realized volatility. Secondly, the steeper the drop, the higher the difference between implied and realized volatility should be. Third, the implied volatility of these options should be higher than that of a control sample. We find strong evidence for all of these hypotheses.

The remainder of the paper is organized as follows: Section 2 provides a summary of the existing literature and how our research contributes. Section 3 describes our data and methodology. Section 4 provides our main results relating to volatility. Section 5 details our trading strategies. We provide a summary and conclude in section 6.

Related Literature

Misreaction in the option market was first documented by Stein in 1989. He finds that there is overreaction in long-term options relative to short-term options. When short-term S&P 100 index options' implied volatility moves, long-term options' implied volatility moves the same amount. Since implied volatility follows a mean-reverting process, it should be the case that the long-term options' implied volatility moves less than that of short-term options. The cause of this mispricing is investor overreaction to new information. Poteshman (2001) documents both longer-term overreaction and shorter-term underreaction in the option market. Our paper adds to this string of research by providing evidence of overreaction to a specific type of information, and linking this overreaction to the stock market. It is also notable that we see this overreaction in the short term, which has not been documented before.

We take as given the relatively new idea that demand is instrumental in option pricing. This literature begins with Bollen and Whaley (2004), who show how investor demand affects the steepness of the implied volatility function of S&P 500 index options and 20 individual stock options. First, the authors document the differences between implied volatility smiles of index options versus individual options. Index smiles monotonically decrease, whereas individual smiles are more symmetric. They also document that demand for puts is dominant in the market for index options, while demand for calls is dominant in the market for individual stock options. Thus, since the demand mechanisms and volatility functions are different for index versus individual options, we may expect different findings for those two categories. For both types of option, the authors find evidence against the null hypothesis modeled by Black-Scholes where demand has no effect on option prices due to a horizontal supply curve. Their evidence suggests that limits to arbitrage lead to demand affecting the shape of the IVF, and therefore the prices of options. The authors also construct a simulated trading strategy in which options are sold and delta-hedged using underlying securities. Before transactions costs, the strategies using index options are profitable, but those using individual stock options are not.

Further evidence that demand determines the price of options is presented in the work of Garleanu, Pedersen and Poteshman (2009). The authors develop a microstructure model showing how the demand of an option affects the prices and skews of that option and other options. In particular, the effect on price from an increase in demand is proportional to the unhedgeable part of that option. The effect on another option's price is proportional to the covariance of the unhedgeable parts of the two options. The authors have a unique dataset containing direct data on demand, and they define net demand as the sum of long open interest minus the sum of short open interest for each investor category. Regressions of daily excess implied volatility, measured as the difference between Black-Scholes implied volatility and historical 60 day volatility (or realized ex-post volatility, or GARCH(1,1)) on net demand produce a positive and statistically significant coefficient. Regressions of excess implied volatility skew on skewness in net demand also produce significantly positive coefficients. Excess implied volatility skew is defined as the average implied volatility from low moneyness options minus that from options with moneyness close to one, with moneyness equal to strike price divided by stock price. The authors are, however, silent on the causes of demand. This is where our paper fits in. Garleanu, Pedersen, and Poteshman provide the theoretical basis for our paper, and we extend their research by identifying a possible demand driver and showing its effect on individual option prices.

Our paper is closely related to Amin, Coval, and Seyhun (2004). Focusing solely on S&P 100 index options, their paper examines the relationship between momentum in stock prices and option prices, with demand being the mechanism that links stock price to option price movements. Two main tests are conducted. The first is an examination of American option put-call parity violations. The authors find that 60-day stock price changes of 5 percent (-5 percent) or more (less) significantly increase the probability that parity will be violated due to high-priced calls (puts). The second test compares the Black-Scholes implied volatility spread between calls and puts following 60-day stock market increases or decreases. They find that following stock market increases, calls become overpriced relative to puts, and following stock market decreases, puts become overpriced relative to calls. Regressions of volatility spread on past stock returns produce positive coefficients. The authors also find that the steepness of the volatility smile is greater following stock market decreases than increases, for both calls and puts. The spirit of our paper is quite similar. However, our paper differs from, and adds to, this research in two important ways. First, we look at the individual equity options that make up the S&P 100, rather than options on the index itself. Second, we look at much shorter and more extreme stock price changes. Thus, we are not focusing on momentum, but rather overreaction to extreme information in the short term.

Several papers provide evidence on the expensiveness of put options on the S&P indices. Coval and Shumway (2001) show that the expected returns of puts are negative, while the expected returns of calls are positive. Bondarenko (2003) generalizes the martingale restriction of the CAPM and the model of Rubinstein (1976) to include an entire class of models. This more general restriction holds even with sample biases and incorrect beliefs of investors. However, put option prices are still too high to be rationally explained. We provide evidence that given a recent sharp decline in stock price, put options on individual equities also become overpriced.

In summary, our contributions to the existing literature are twofold. We extend the work of Coval and Shumway (2001), Amin, Coval, and Seyhun (2004) and Bondarenko (2003) on index options to the market for options on individual stocks. We provide evidence on the overpricing of individual equity options, as well as short-term investor overreaction in the options market to stock price changes. We extend the work of Bollen and Whaley (2004) and Goyal and Saretto (2009) in terms of trading strategies. Following the methodology of Bollen and Whaley, we find that after conditioning on past stock returns, a strategy of selling individual stock options and delta hedging is profitable before trading costs, whereas they did not find any significant profits without said conditioning. Thus, we show that investors consistently overreact in the options market for individual stocks, and this overreaction can be taken advantage of via an appropriate trading strategy.

Data And Methodology

Our empirical tests involve options on S&P 100 stocks from 1996 to 2004. Using these stocks will reduce problems from small stock biases and liquidity issues. Option data are obtained from Ivy DB OptionMetrics. This database includes implied volatilities, which are computed using a binomial tree that incorporates the early exercise feature (individual equity options are American options). We also use this dataset for bid and offer option prices, exercise prices, maturity dates, volume, and option deltas. Each option we use must have a positive volume, positive implied volatility, and a best bid price greater than $0.24. We obtain stock prices from the CRSP database, and require that prices be available every day while a position is open for the purpose of computing holding returns and realized volatilities. We define moneyness as strike price divided by stock price; deepest out-of-the-money puts (in-the-money calls) have moneyness less than 0.85, at-the-money options have moneyness between 0.95 and 1.05, and deepest in-the-money puts (out-of-the-money calls) have moneyness greater than 1.15. For robustness, we also conduct our analysis using option delta as moneyness. We sort options according to moneyness category and days to maturity. Our analysis is performed using the averages of implied volatility and expensiveness for each moneyness/maturity combination.

We perform our analysis in event time, an event being a stock price change of greater than 10 percent or greater than 20 percent in either direction during a five-day window. To avoid counting the same event twice, we require that no event has occurred in the prior five days. Our measure of expensiveness is the Black-Scholes implied volatility minus the ex-post realized volatility of the underlying stock over the remaining life of the option. We compare this measure across moneyness categories, holding maturity constant. Our hypothesis is that, due to demand pressure sparked by a steep stock price decline, out-of-the-money puts will become overpriced. We also expect that a steeper stock price drop will result in more pronounced put overpricing. Since the volatility implied by the Black-Scholes formula is not an ideal measure, we do not focus on absolute magnitudes, but rather employ three benchmarks. The first is to look at the difference in expensiveness following a stock price increase and decrease of the same percentage (i.e., 10 percent or 20 percent), and the second is to look at two different levels of drops and increases (i.e., a 10 percent drop (increase) versus a 20 percent drop (increase)). The third is a control sample which excludes any options which have a stock price event in the previous five days.

Main Volatility Results

The first results in this paper relate to the difference between implied volatility of an option and the realized volatility of its underlying following underlying stock price movements. This is our measure of expensiveness. Since implied volatility is a forward-looking measure, the most appropriate comparison is with the ex-post realized volatility for the remaining life of the option, rather than historical volatility measures. We find that implied volatility is driven up very high following extreme stock price movements—in fact, it is too high, since the actual realized volatility turns out to be much lower in truth.

ACRN Journal of Finance and Risk Perspectives
Vol. 1, Issue 2, p. xxx-yyy, Dec. 2012
ISSN 2305-7394

Table 1: Unconditional Implied Volatilities

Moneyness (X/S)	<0.85	0.85-0.95	0.95-1.05	1.05-1.15	>1.15
Panel A: Calls					
<31 Days To Maturity	0.713	0.398	0.314	0.398	0.611
31-61 Days To Maturity	0.512	0.354	0.304	0.341	0.481
61-91 Days To Maturity	0.458	0.337	0.296	0.315	0.427
>91 Days To Maturity	0.400	0.327	0.299	0.297	0.358
Panel B: Puts					
<31 Days To Maturity	0.744	0.450	0.323	0.370	0.620
31-61 Days To Maturity	0.561	0.380	0.310	0.331	0.477
61-91 Days To Maturity	0.493	0.351	0.304	0.318	0.423
>91 Days To Maturity	0.406	0.325	0.305	0.311	0.366

Implied volatilities are reported, without conditioning on prior stock returns. Call and put options are sorted by moneyness and days to maturity. Moneyness is defined as strike price divided by stock price.

Table 2: Implied Volatilities Following Extreme 5-Day Returns (+/-10%)

Moneyness (X/S)	<0.85	0.85-0.95	0.95-1.05	1.05-1.15	>1.15
Panel A: Calls After At Least 10% Return					
<31 Days To Maturity	0.826	0.542	0.481	0.527	0.679
31-61 Days To Maturity	0.644	0.486	0.458	0.472	0.594
61-91 Days To Maturity	0.589	0.465	0.450	0.452	0.537
>91 Days To Maturity	0.529	0.456	0.441	0.440	0.492
Panel B: Calls After At Most -10% Return					
<31 Days To Maturity	0.998	0.649	0.578	0.599	0.750
31-61 Days To Maturity	0.737	0.572	0.532	0.520	0.623
61-91 Days To Maturity	0.664	0.522	0.496	0.486	0.547

Panel B: Calls After At Most -10% Return					
>91 Days To Maturity	0.591	0.501	0.484	0.469	0.503
Panel C: Puts After At Least 10% Return					
<31 Days To Maturity	0.793	0.570	0.500	0.536	0.758
Panel C: Puts After At Least 10% Return					
31-61 Days To Maturity	0.664	0.505	0.468	0.483	0.605
61-91 Days To Maturity	0.603	0.479	0.457	0.463	0.577
>91 Days To Maturity	0.545	0.458	0.446	0.457	0.523
Panel D: Puts After At Most -10% Return					
<31 Days To Maturity	0.907	0.647	0.551	0.550	0.817
31-61 Days To Maturity	0.751	0.575	0.522	0.516	0.648
61-91 Days To Maturity	0.677	0.520	0.489	0.482	0.579
>91 Days To Maturity	0.591	0.487	0.477	0.463	0.524

Implied volatilities are reported conditioned on a prior 5-day stock return of at least 10 percent in magnitude. Call and put options are sorted by moneyness and days to maturity. Moneyness is defined as strike price divided by stock price.

Unconditional implied volatilities are presented in Table 1. This table provides a base case against which to compare our conditional results. These implied volatilities are in line with those reported by previous studies, and show the typical volatility smile, which is steeper for shorter maturity options. Table 2 reports implied volatilities conditional on stock price events of at least 10 percent in magnitude. After such an event, all of the implied volatilities are higher than the unconditional implied volatilities. Negative price movements appear to have a larger impact on implied volatilities than do positive price movements, although there is a caveat that the price events may not be of the same magnitudes on either side. Table 3 reports similar findings, this time conditioning on even more extreme stock price movements of at least 20 percent in magnitude. As expected, the implied volatilities shoot up even higher.

ACRN Journal of Finance and Risk Perspectives
Vol. 1, Issue 2, p. xxx-yyy, Dec. 2012
ISSN 2305-7394

Table 3: Implied Volatility Minus Realized Volatility Following Extreme 5-Day Returns (+/-10%)

Moneyness (X/S)	<0.85	0.85-0.95	0.95-1.05	1.05-1.15	>1.15
Panel A: Calls After At Least 10% Return					
<31 Days To Maturity	0.261	-0.017	-0.068	-0.056	0.029
31-61 Days To Maturity	0.107	-0.040	-0.056	-0.062	-0.010
61-91 Days To Maturity	0.029	-0.074	-0.091	-0.096	-0.034
>91 Days To Maturity	-0.008	-0.090	-0.086	-0.092	-0.050
Panel B: Calls After At Most -10% Return					
<31 Days To Maturity	0.296	0.028	-0.058	-0.057	0.026
31-61 Days To Maturity	0.139	0.004	-0.072	-0.080	-0.023
61-91 Days To Maturity	0.085	-0.014	-0.085	-0.101	-0.058
>91 Days To Maturity	0.029	-0.073	-0.100	-0.101	-0.079
Panel C: Puts After At Least 10% Return					
<31 Days To Maturity	0.176	0.004	-0.053	-0.025	0.141
31-61 Days To Maturity	0.102	-0.026	-0.036	-0.056	0.022
61-91 Days To Maturity	0.031	-0.049	-0.071	-0.073	0.005
>91 Days To Maturity	0.026	-0.058	-0.059	-0.071	-0.013
Panel D: Puts After At Most -10% Return					
<31 Days To Maturity	0.253	0.038	-0.046	-0.053	0.164
31-61 Days To Maturity	0.144	0.003	-0.063	-0.056	0.047
61-91 Days To Maturity	0.114	-0.031	-0.069	-0.112	-0.009
>91 Days To Maturity	0.051	-0.069	-0.087	-0.080	-0.052

This table shows our measure of expensiveness of options, conditioned on a prior 5-day stock return of at least 10 percent in magnitude. A positive number indicates an overpriced option. Moneyness is defined as strike price divided by stock price. Implied volatility is from OptionMetrics, and is calculated using a binomial model. Realized volatility is the stock's volatility *over the remaining life of the option following an extreme stock price movement. It is calculated as* $rv = \sum_{i=1}^{N} \sqrt{252 * R_i^2}$ *, where* R_i *is the daily stock return, and i indexes the stocks in the sample which have met the prior 5-day return requirements.*

High implied volatilities on their own do not imply overpricing. Table 4 compares these implied volatilities to the volatilities actually realized over the remaining life of the options. Since implied volatility is supposed to be a predictor of the ex-post volatility, it is interesting to see how far off it actually is following these stock price events. Following a stock price decrease of at least 10 percent, short-term out-of-the-money puts have an implied volatility which is 25.3 percent higher than the actual realized volatility. Following at least a 20 percent drop, this difference increases to 27.5 percent.

.

Table 4: Unconditional Implied Volatility Minus Realized Volatility

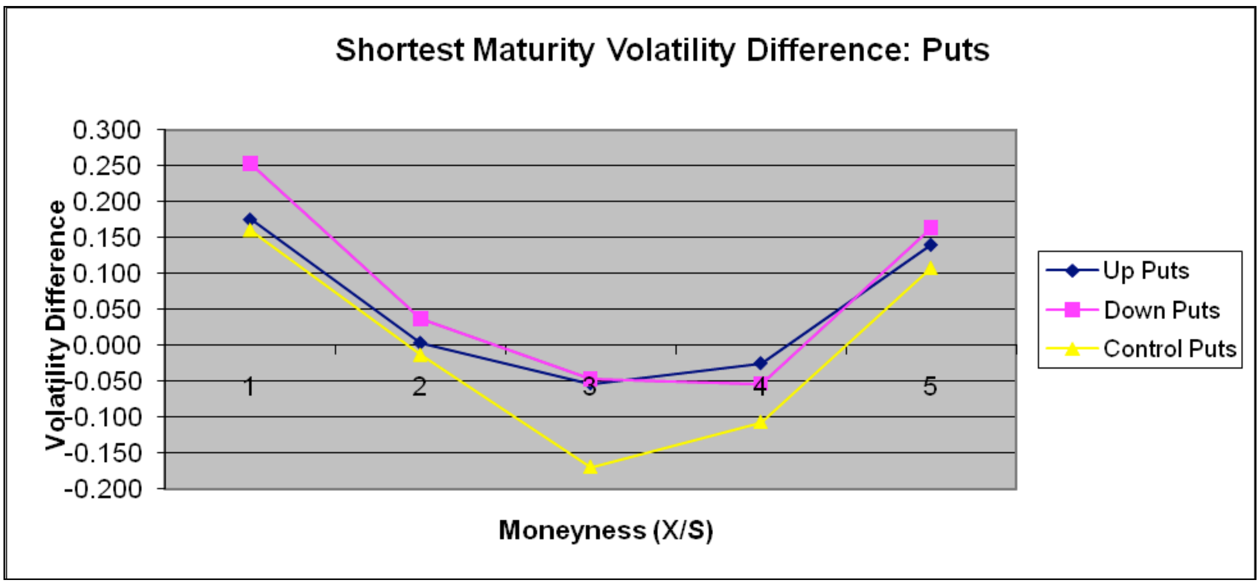
Moneyness (X/S)	<0.85	0.85-0.95	0.95-1.05	1.05-1.15	>1.15
Panel A: Calls					
<31 Days To Maturity	0.251	-0.088	-0.180	-0.125	-0.007
31-61 Days To Maturity	0.048	-0.138	-0.208	-0.200	-0.067
61-91 Days To Maturity	-0.002	-0.131	-0.190	-0.173	-0.072
>91 Days To Maturity	-0.074	-0.183	-0.219	-0.220	-0.138
Average	0.056	-0.135	-0.199	-0.179	-0.071
Panel B: Puts					
<31 Days To Maturity	0.161	-0.013	-0.169	-0.106	0.108
31-61 Days To Maturity	0.078	-0.106	-0.198	-0.157	-0.016
61-91 Days To Maturity	0.023	-0.110	-0.169	-0.142	-0.019
>91 Days To Maturity	-0.046	-0.156	-0.188	-0.170	-0.073
Average	0.054	-0.096	-0.181	-0.144	0.000

This table shows our measure of expensiveness of options, unconditionally. A positive number indicates an overpriced option. Moneyness is defined as strike price divided by stock price. Implied volatility is from OptionMetrics, and is calculated using a binomial model. Realized volatility is the stock's volatility over the remaining life of the option following an extreme stock price movement. It is calculated as $rv = \sum_{i=1}^{N} \sqrt{252 * R_i^2}$ *, where* R_i *is the daily stock return, and i indexes the stocks in the sample.*

As a benchmark, these numbers can be compared to the average unconditional volatility differences for short term puts of 16.1 percent, reported in Table 4. The volatility difference for short-term, out-of-the-money puts following the 10 percent stock price drop is about twice as high as it is unconditionally, and this difference is significant at the 5 percent level (t-statistic 2.27). It should be noted that while this volatility difference is most pronounced for short-term out-of-the-money put options, it remains positive across all moneyness categories and all maturities, as well as for calls (following the 10 percent minimum drop). It is also striking that following 10 percent and 20 percent minimum increases in stock price, there is a significant difference between implied and realized volatility as well. The relationship between volatility differences following 10 percent decreases, 10 percent increases and without conditioning upon stock price changes can be seen in Figure 1.

Figure 1: Shortest Maturity Volatility Difference

When Absolute Return Is Greater Than 10%: Puts



While there are many possible explanations for the observed relationship, we believe that the likely reason for the “negative shock” graph in Figure 1 being highest is that following stock decreases, people tend to panic, and their increased demand drives the put prices (and by put-call parity, the call prices) up too high. This theory is supported by data on trading volume, which are shown in Figure 2. This figure shows the number of short-term, out-of-the-money put options traded on a daily basis surrounding a five-day stock price decrease of 10 percent. In the figure, Day 0 corresponds to the trading day after the five-day stock price drop has been recorded. The figure is consistent with the fact that our choice of five days for a stock price event is somewhat arbitrary, but is a reasonable timeframe. We can see that the volume increases sharply at Day -2, and stays high for several more days before tapering off. As for a positive shock, following a sharp price increase, investors may become too exuberant, pushing the price of calls too high in an attempt to lever up their investments. This investor overreaction helps explain why following stock price movements, there is an increased difference between realized and implied volatilities. It also helps explain why this difference increases the sharper is the stock price movement—investors simply tend to panic (or conversely, get excited) more as movement increases.

Given the large magnitude of these differences, and hence the expensiveness of options, the natural question which arises is how sophisticated investors can systematically take advantage of this overreaction in the option market. This leads us to the next section, which focuses on trading strategies.

Trading Strategies

A good question to ask when hearing about security mispricing is, "Can I profit from this?" In this section, we construct trading strategies which take advantage of the overpriced, short-maturity, out-of-the-money puts. We follow the general methodology of Bollen and Whaley (2004) in order to be able to compare our results to theirs. We find that when conditioning the strategy on prior stock price performance, we find statistically significant profits (before trading costs) from selling the overpriced puts and delta-hedging daily until the option's expiration date, and from variations on this strategy.

From the results reported in the previous section, we see that the most extreme overpricing of puts occurs in the shortest maturity, deepest out-of-the-money options. The anecdotal evidence from the Wall Street Journal also points us in the direction of the shortest maturity options. These will also have the fewest liquidity problems. For these reasons, this is where we focus our strategy—we use options with 30 days or less left to maturity and moneyness (strike divided by stock price) of 0.85 or less. The average position is held for 15 days, so we also present returns rescaled on a monthly basis for purposes of comparison. We adjust for the dividends paid during the time the position is held, and use the one-month Treasury bill rate as the risk-free rate. We condition on stock market movements in the following way: we open a position only after observing a five-day drop of 10 percent or more in a stock's price. As before, to avoid double counting, we do not allow more than one stock price event to occur in any five-day period.

In our first strategy, we sell the overpriced puts at the bid-ask midpoint and delta-hedge the position on a daily basis once an event is observed. The returns to this strategy are computed according to the following formula:

$$(1)\qquad RET = \frac{|\Delta_0|(S_0e^{rT} - S_T - \sum_{t=0}^{T} D_t e^{r(T-t)}) + (p_0e^{rT} - p_T) + \sum_{t=0}^{T} |\Delta_t|(S_t - S_{t+1} - D_t)e^{r(T-t)}}{|\Delta_0|S_0 + p_0}$$

where Δ_t is the option delta on date *t*, S_t is the closing price of the stock on date *t*, D_t is the dividend paid on the stock at date *t*, p_0 is the price of the option on the date the position is opened, p_T is the greater of zero or the strike price of the option minus the stock price on the expiration date of the option, and *r* is the risk-free rate. Since we are selling both the puts and the stock, there is no initial outlay; instead, there is an inflow. So, the returns to the trading strategy can be interpreted as the amount of the initial inflow that we get to keep after the positions are closed out.

Table 5: Trading Strategy Results

	(A)	(B)	(C)
	Strategy 1:	Strategy 2:	Strategy 3:
	Sell put at bid-ask midpoint, daily delta-hedge	Sell put at bid, daily delta-hedge	Sell put at bid, initial delta hedge only
Panel A: Conditional on Stock Price Drop			
$ per transaction	$0.81	$0.77	$0.27
	(11.23)	(10.54)	(4.99)
% per transaction	11.88%	11.02%	3.45%
	(10.84)	(9.90)	(4.53)
30-day %	17.12%	15.91%	4.81%
	(10.99)	(10.10)	(4.24)
Panel B: Control Sample			
$ per transaction	$0.42	$0.37	$0.31
	(2.74)	(2.39)	(3.14)
% per transaction	6.57%	5.74%	4.05%
	(3.78)	(3.29)	(3.51)
30-day %	8.96%	7.97%	5.69%
	(4.39)	(3.89)	(4.14)

This table shows the profits generated by three trading strategies. Panel A presents results conditional on stock price movements. For all three strategies, positions are only opened after a stock price decrease of at least 10 percent. Panel B presents results from the control sample. Strategy 1 sells puts at the bid-ask midpoints and delta hedges, adjusting the hedge on a daily basis. Strategy 2 is the same as Strategy 1, except puts are sold at the bid price. Strategy 3 sells puts at the bid price and delta hedges when the position is opened, and does not adjust the delta hedge. The first row shows the average profit per position, the second row shows the returns to the strategy, which are interpreted as the percentage of the initial inflow the investor ultimately keeps, and the third row adjusts the returns so they are on a monthly basis. T-statistics have not been corrected for cross-correlation, and so will actually be lower

The first term in the numerator is the gain or loss from selling delta shares of the underlying at the time the position is opened, and holding those shares until the position is closed out at the expiration date of the option. The second term in the numerator is the gain or loss from selling the put and closing out the position at the expiration of the option. The third term of the numerator accounts for the daily gains or losses resulting from adjusting the delta hedge on a daily basis. The denominator simply gives us a way to scale and compare profits. As reported in Panel A of Table 5, the per transaction profit is \$0.81 (t-statistic 11.23), and the 30-day return to this strategy is 17.12 percent (t-statistic 10.99). The second strategy mirrors the first, but with the puts being sold at the bid price, rather than at the bid-ask midpoint. This takes into account the trading costs from selling the option. This strategy produces a per transaction profit of \$0.77 (t-statistic 10.54); the 30-day return is 15.91% (t-statistic 10.10). As a back-of-the-envelope calculation of trading costs on the stock, we assume that these hedging transactions are done in large amounts, and commissions on S&P 100 stocks are about \$0.05 per share. Since the average position is held for 15 days, and the average total number of shares sold is less than two, incorporating trading costs reduces our profits from \$0.77 to about \$0.67. Our third strategy is a way around the costs of daily delta-hedging. In this strategy, we delta-hedge on the day the position is opened, and simply hold that stock position until the option expires. Thus, we significantly cut our transaction costs of delta-hedging. The returns to this strategy are calculated as follows:

$$RET = \frac{|\Delta_0|(S_0 e^{rT} - S_T - \sum_{t=0}^{T} D_t e^{r(T-t)}) + (p_0 e^{rT} - p_T)}{|\Delta_0| S_0 + p_0} \tag{2}$$

Here, all terms are defined as before. The only change in return computation is the omission of the term calculating mark-to-market gains and losses. The per-transaction profit to this strategy (before trading costs) is \$0.27 (t-statistic 4.99), and the 30-day return is 4.81 percent (t-statistic 4.24).

To verify that these returns are abnormal, we constructed a control sample and ran the same analysis. The control sample was constructed to exclude the options that are included in our main results. Thus, none of the positions held in the control sample strategy have experienced a stock price event in the previous five days. The positions that are opened were randomly chosen and have a similar sample size to the previous results. Results are reported in Panel B of Table 5. For strategies 1 and 2, the returns are about half that of the conditional strategy, and are not as strongly significant. Strategy 3 does not outperform the control sample. As another robustness check, we ran these strategies without opening any positions in the five days before option expiration with nearly identical results. We have also tested the strategies using delta to define moneyness, with similar results.

Table 6: Aggregate Results Per Company Per Open Date

	(A) Strategy 1: Sell put at bid-ask midpoint, daily delta-hedge	**(B)** Strategy 2: Sell put at bid, daily delta-hedge	**(C)** Strategy 3: Sell put at bid, initial delta hedge only
$ per transaction	$1.49	$1.41	$0.60
	(7.38)	(7.07)	(3.28)
% per transaction	19.17%	17.97%	6.87%
	(9.22)	(8.63)	(4.07)
30-day %	32.49%	30.51%	12.80%
	(9.28)	(8.68)	(4.56)

This table shows the profits generated by three trading strategies when our positions are aggregated by company. When a stock meets the prior return requirement, all that stock's puts (which meet selection criteria) are combined into a single short position. For all three strategies, positions are only opened after a stock price decrease of at least 10 percent. Strategy 1 sells puts at the bid-ask midpoints and delta hedges, adjusting the hedge on a daily basis. Strategy 2 is the same as Strategy 1, except puts are sold at the bid price. Strategy 3 sells puts at the bid price and delta hedges when the position is opened, and does not adjust the delta hedge. The first row shows the average profit per position, the second row shows the returns to the strategy, which are interpreted as the percentage of the initial inflow the investor ultimately keeps, and the third row adjusts the returns so they are on a monthly basis

Next we address the problem of having non-independent observations, which comes from the fact that we have more than one option per stock for a given event day when we open a position. To adjust for this, we add together all the positions for a given company on a given position-open day. This means we now have one aggregate position per company, rather than several separate positions. As shown in Table 6, our returns to each strategy are higher. The t-statistics decrease but are still very high.

Table 7: Calendar-Time Strategy Results

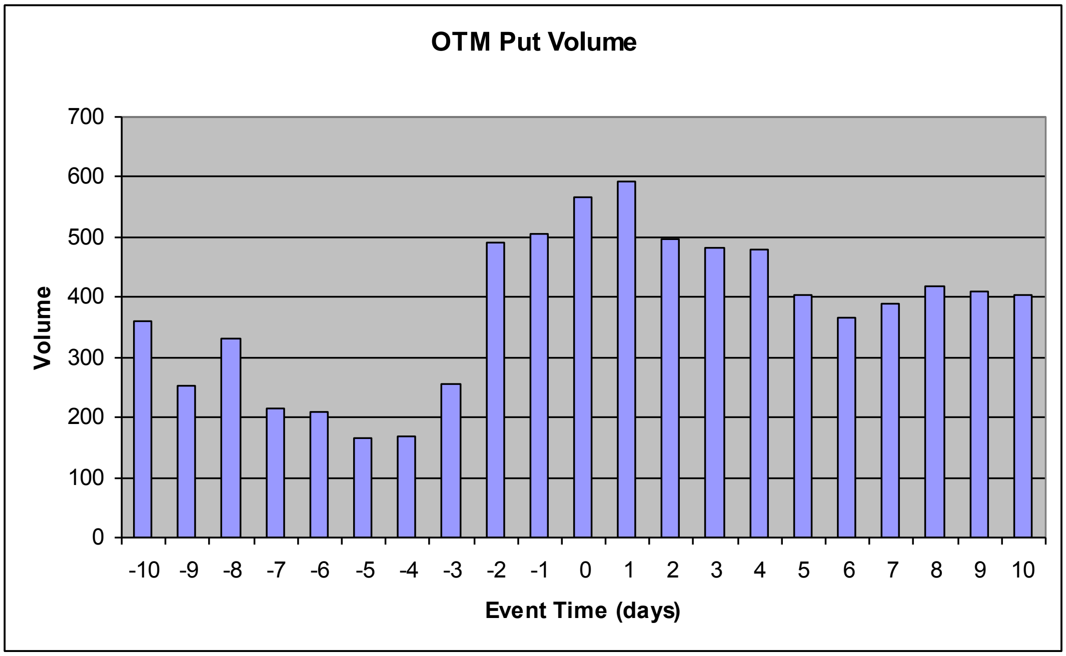
	(A)	(B)	(C)
	Strategy 1:	Strategy 2:	Strategy 3:
	Sell put at bid-ask midpoint, daily delta-hedge	Sell put at bid, daily delta-hedge	Sell put at bid, initial delta hedge only
Monthly Return	10.50%	9.50%	4.03%
	(7.60)	(6.80)	(2.70)
Sharpe Ratio	1.00	0.88	0.35

This table shows the monthly return to each of the three strategies when implemented in calendar time. For all three strategies, positions are only opened after a stock price decrease of at least 10 percent. Strategy 1 sells puts at the bid-ask midpoints and delta hedges, adjusting the hedge on a daily basis. Strategy 2 is the same as Strategy 1, except puts are sold at the bid price. Strategy 3 sells puts at the bid price and delta hedges when the position is opened, and does not adjust the delta hedge. The Sharpe ratio for each strategy is also presented, and t-statistics are shown in parentheses.

We also conduct our trading strategy in calendar time and find significantly positive returns. Doing this demonstrates that the strategy is implementable for a real-world investor. Results are reported in Table 7. When selling puts at the bid-ask midpoint, the strategy earns 10.5 percent per month (t-statistic 7.6), with a Sharpe ratio of 1.00. More realistically, when puts are sold at the bid price, the strategy earns 9.5 per month (t-statistic 6.8), with a Sharpe ratio of 0.89. Furthermore, Figure 3 shows that this strategy earns positive returns in nearly every month in which positions are held from 1996 to 2004.

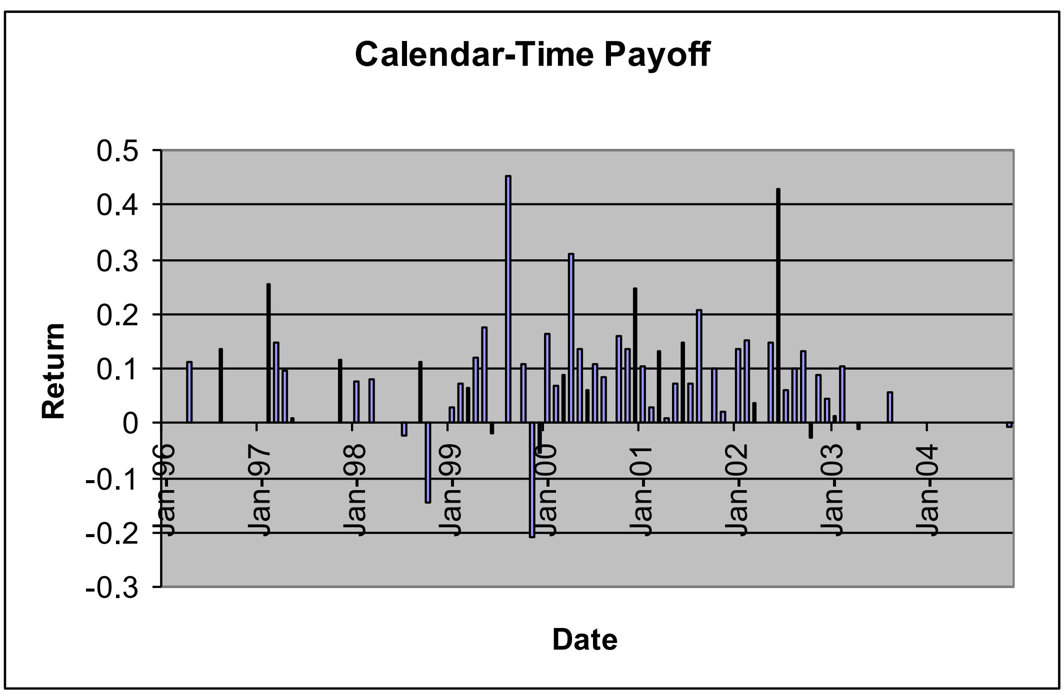
ACRN Journal of Finance and Risk Perspectives
Vol. 1, Issue 2, p. xxx-yyy, Dec. 2012
ISSN 2305-7394

Figure 2: Put Option Volume Around Extreme Stock Price Drops



This figure shows number of short-term, out-of-the-money put contracts traded on a daily basis surrounding a 5-day stock price drop of at least 10 percent. Day 0 corresponds to the trading day after the 5-day price drop was recorded.

Figure 3: Calendar-Time Trading Strategy Returns



Three-factor model regression results are shown in Table 8. When the dependent variable of the monthly return (selling at the bid) minus the risk-free rate is regressed on the three standard Fama-French factors, it produces an alpha of 9.39 (t-statistic 7.24). In addition to positive average returns, we also find that our first two strategies earn a profit over 84 percent of the time, while the single delta-hedge strategy earns a profit over 63 percent of the time.

Table 8: Fama-French Three Factor Model Results

	Estimate	t-statistic
Alpha	9.39	7.24
MRP	-0.72	-2.32
SMB	0.10	0.35
HML	0.42	1.14

This table reports the results of regressions of monthly calendar returns on the market risk premium, size factor and book-to-market factor. The dependent variable is the return from Strategy 2, where put options are sold at the bid price after a stock price decrease of at least 10 percent has been observed, and delta hedging is performed daily.

Summary And Conclusion

In this paper, we start by examining the difference between implied volatility and realized volatility of individual stocks in the S&P 100 following sharp price movements, as a method of determining the expensiveness of options. We find that following a stock price decrease of at least 10 percent, implied volatility of puts exceeds the ex-post realized volatility of the underlying stock by 25.3 percent. For a stock price drop of at least 20 percent, the volatility difference is 27.5 percent.

One possible explanation for this difference is that put options become overpriced following extreme recent stock price drops due to the demand generated by panicking investors. Following stock price increases, call options become similarly overpriced. The rationale here is that investors become overly excited following sharp price run-ups and buy calls to take advantage of further expected run-ups in stock prices.

Given the large difference between implied and realized volatilities, there should be a way to systematically profit from writing stock options. We examine three trading strategies. We follow the methodology of Bollen and Whaley (2004), with the exception that we confine our option sales to times following a significant stock drop (later work will include trading strategies following stock price increases). In their paper, Bollen and Whaley found that there was no way of systematically profiting from a trading strategy involving writing options. Our work shows that one can profit significantly from selling options, provided they do so following significant stock price movements.

Overall, our paper follows most closely in the spirit of Amin, Coval and Seyhun (2004) and Bollen and Whaley (2004). While the former examines index option prices following stock price movements, our paper complements it by doing similar work with individual stock options. The latter paper examines trading strategies (in addition to explaining how demand drives implied volatility) for both individual equities and the S&P 100 index. We find results which extend theirs by conditioning the trading strategies on stock price movements. We are able to find a systematic way of profiting from selling individual stock options.

References

Amin, K., Coval, J., & Seyhun, H. (2004). Index Option Prices and Stock Market Momentum. *Journal of Business,77*(4), 835-873.

Barberis, N., Shleifer, A., & Vishny, R. (1998). A Model of Investor Sentiment. *Journal of Financial Economics, 49*(3), 307-343.

Bates, D. (1991). The Crash of '87: Was It Expected? The Evidence From Options Markets. *The Journal of Finance, 46*(3), 1009-1044.

Bates, D. (2000). Post '87 Crash Fears in the S&P 500 Futures Options Market. *Journal of Econometrics, 94*(1-2), 181-238.

Black, F., & Scholes, M. (1973). The Pricing of Options and Corporate Liabilities. *Journal of Political Economy, 81*(3), 637-659.

Bollen, N., & Whaley, R. (2004). Does Net Buying Pressure Affect the Shape of Implied Volatility Functions? *The Journal of Finance, 59*(2), 711-753.

Bondarenko, O. (2003). *Why Are Put Options So Expensive?* Paper presented at the AFA 2004 San Diego Meetings, San Diego, CA.

Coval, J., & Shumway, T. (2001). Expected Option Returns. *The Journal of Finance, 56*(3), 983-1009.

De Long, J., Shleifer, A., Summers, L., & Waldmann, R. (1990). Noise Trader Risk in Financial Markets. *Journal of Political Economy, 98*(4), 703-738.

Fama, E., & French, K. (1993). Common Risk Factors in the Returns on Stock and Bonds. *Journal of Financial Economics, 33*(1), 3-56.

Figlewski, S. (1989). Option Arbitrage in Imperfect Markets. *The Journal of Finance, 44*(5), 1289-1311.

Garleanu, N., Pedersen, L., & Poteshman, A. (2009). Demand-Based Option Pricing. *Review of Financial Studies, 22*(10), 4259-4299.

Goyal, A., & Saretto, A. (2009). Cross-section of Option Returns and Volatility. *Journal of Financial Economics, 94*(2), 310-326.

Hong, H., & Stein, J. (1999). A Unified Theory of Underreaction, Momentum Trading and Overreaction in Asset Markets. *The Journal of Finance, 54*(6), 2143-2184.

Lakonishok, J., Lee, I., Pearson, N., & Poteshman, A. (2007). Option Market Activity. *Review of Financial Studies, 20*(3), 813-857.

Lo, A., & Wang, J. (1995). Implementing Option Pricing Models When Asset Returns Are Predictable. *The Journal of Finance, 50*(1), 87-129.

Poteshman, A. (2001). Underreaction, Overreaction, and Increasing Misreaction to Information in the Options Market. *The Journal of Finance, 56*(3), 851-876.

Shleifer, A., & Vishny, R. (1997). The Limits of Arbitrage. *The Journal of Finance, 52*(1), 35-55.

Stein, J. (1989). Overreactions in the Options Market. *The Journal of Finance, 44*(4), 1011-1023.