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On profitability of volatility trading on S&P 500 equity index options: The role of trading frictions

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ABSTRACT

This article examines the profitability of volatility trading on S&P 500 equity index options in time-varying market conditions, with a particular focus on evaluating the authenticity of risk-adjusted returns. While significant profits are available on strategies that involve writing put options, our findings cast doubt on whether these profits can be genuinely attained in practice. After bid-ask spreads are included, we find that the profitability is significantly reduced. Furthermore, the implementation of the trades is generally difficult owing to margin requirements as investors have to set aside a large proportion of their wealth into margin accounts and also face a high likelihood of margin calls. Overall, the profitability of volatility trading tends to hinge on the capability of investors to capture the volatility risk premium and to wisely time its trades.

1. Introduction

Since the seminal work of Black and Scholes (1973), extensive research has been performed to study both the theoretical and empirical properties of option prices (returns), leading to a diverse literature.[1] One particular topic of direct interest to investors is to examine the profitability of option trading to have knowledge on how to maximize their utilities. Coval and Shumway (2001), Bakshi and Kapadia (2003), Jones (2006), Driessen and Maenhout (2007), and Bondarenko (2014) find that strategies which involve writing put options on the S&P 500 generate unusually high risk-adjusted returns, with Sharp ratios being close to 2 on an annual basis particularly for writing straddles and strangles. The potential reasons for the exceptionally large profits earned by those trades are remuneration for volatility and jump risk, demand pressure, non-standard preferences, and market segmentation (see Bates, 2003 for a review).

Two recent papers, Santa-Clara and Saretto (2009) and Do, Foster, and Gary (2016), however, greatly challenge previous studies by accounting for the impact of trading frictions on the profitability of option trading, which is more applicable in real-world settings. After the consideration of both bid-ask spreads and margin requirements, the authors find that profits realizable by an investor are actually not as large as previously documented. The findings therefore bring into attention the significance of trading frictions when the investor hedges, arbitrages or speculates in option markets.

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[1] Primary theoretical breakthroughs include the stochastic volatility model (Heston, 1993; Hull & White, 1987), the jump model (Bates, 1996), and the double jump model (Duffie, Pan, & Singleton, 2000).

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Given the vital role of trading frictions in determining a strategy's success, in this study we re-examine the profitability of option trading while accounting for the impact of trading frictions. In contrast with previous research, this study focuses on a wide range of volatility trades, which, to the best of our knowledge, makes it broader than any other option strategy analysis in the literature: in addition to straddles that are widely tested in the extant literature (Broadie, Chernov, & Johannes, 2009; Driessen & Maenhout, 2013; Duarte & Jones, 2007; Santa-Clara & Saretto, 2009), we also include strangles, guts, strips, straps as well as butterflies that are covered in several financial text books such as Hull (2009) and McDonald (2012). The lack of attention on these trading positions might be attributed to their lower frequency of use in practice. As documented in Chaput and Edrington (2005), among the volatility trades which account for 25% of the Eurodollar futures option market trades, straddles alone have a proportion of 62%, with straddles, strangles and option/asset combinations altogether sharing 94%. The fact that positions excluding the straddles are less actively traded indicates that they may not produce "appealing" profits but certainly need further investigation as they could benefit investors in one or another aspect.

In addition, we also consider the profitability of volatility trading in time-varying market conditions. The volatility surface becomes skewed in the likelihood of extreme shocks such as the market crashes in October 1987 and in September 2008 (Fung, 2005; Orosi, 2012; Rubinstein, 1994; Tzang, Wang, & Yu, 2016), which points to possibly changed option returns. By testing both a pre-crisis and an after-crisis sample data, we can reduce the peso problem, where put options seem overpriced compared to call options when large downward movements take place.

Specifically, we examine the performance of 18 volatility trading strategies on the S&P 500 equity index (SPX) options during the sample periods from January 2002 to December 2007 and from January 2008 to December 2013 and label it as a baseline study. The performance is then compared with two benchmark strategies, a buy-and-hold strategy that invests in the equity index all the time and a short 10% out-of-money (OTM) put which is constantly observed by academics as the most profitable position in option trading (Bondarenko, 2014; Doran & Fodor, 2008). If the strategies are economically important to an investor, one would expect them to have higher risk-adjusted returns. The results show that short volatility strategies are associated with higher Sharpe ratios than the benchmarks.

However, our examination of the authenticity of trading profits provides evidence in a different light. When trading frictions in the form of bid-ask spreads are included, the profitability of volatility trading is significantly reduced though not eliminated. None strategies can beat the benchmarks consistently across both sample periods. In order to earn significant profits, an investor must be capable to identify the right strategy and execute at the right time. For instance, if the investor is intelligent to time the volatility using the short 10% strangle and hold for 30 days before the crisis in 2008, he will be able to reap a huge profit, with an average return of 89.86% on a monthly basis and a Sharpe ratio of 1.67.

The empirical analysis also highlights the importance of margin requirements when estimating short volatility profits. In this context, the strategies like the short 10% strangle that are profitable after bid-ask spreads are generally affected as it is difficult to execute the positions because investors can only invest a small percentage of their wealth in the position and are also subject to having adequate funds to cover margin calls. In other words, margin requirements make it difficult to take advantage of profits from volatility trading and this particularly applies to a wealth constrained investor. Overall, our findings suggest that the modest trading profits which survive real-world settings appear to be contingent on the capability of investors to capture the volatility risk premium and to wisely time its trades.

The reminder of the paper is organized as follows: Section 2 describes data and methodology. In Section 3, empirical results from both the baseline study and the investigation of the authenticity of trading profits are presented and discussed. Section 4 concludes the paper.

2. Data and methodology

2.1. Data selection

Trading of the SPX options occurs on the Chicago Board Options Exchange (CBOE), with regular trading hours between 8.30 a.m. and 3.15 p.m. local time. The option contracts are priced with the value of the S&P 500 index which is a capitalization-weighted index of 500 stocks covering a wide range of industries in the US. The contracts have expiration dates of up to 12 near-term months and are settled with the opening sales prices of the last business trading day which is usually the third Friday of each month. As the index is a non-tradable asset, all settlements on SPX contracts are cash settlements.

The core data for this study comprises daily observations of the SPX European style options over a twelve year period, from January 2002 to December 2013. Time-stamped intraday transaction prices are sourced from the CBOE. The period is further partitioned into two sub-periods, i.e. January 2002 to December 2007 (pre-crisis) and January 2008 to December 2013 (after-crisis), and this study will examine the performance of volatility trading strategies in these two sample periods. The VIX index, constructed with the S&P 500 over a thirty day period, increases from an average daily value of 18% to 23.84% with the standard deviation increasing from 6.80% to 10.97% between these two sample periods. Furthermore, there are more jumps and volatility jumps in the second period.

The option data used in this study are screened using the approach similar to Driessen, Maenhout, and Vilkov (2009) and Goyal and Saretto (2009). Firstly, all option observations that violate the no arbitrage condition are removed, that is, observations for call options if

Table 1
Volatility strategies with Greeks.

Strategy	Holding Position	Delta	Gamma	Vega	Theta
SPX	Buy Market Index	≈1	N/A	N/A	N/A
Short OTM Put	Sell 1 OTM Put	Negative	Negative	Negative	Positive
Long Straddle	Buy 1 ATM Call and Put	≈0	Positive	Positive	Negative
Short Straddle	Sell 1 ATM Call and Put	≈0	Negative	Negative	Positive
Revision Straddle	Long Straddle When Historical Volatility (HV) – Implied Volatility (IM) >0, Short Straddle When HV– IM < 0	≈0	Varies	Varies	Varies
Long Strangle	Buy 1 OTM Call and Put	≈0	Positive	Positive	Negative
Short Strangle	Sell 1 OTM Call and Put	≈0	Negative	Negative	Positive
Long Gut	Buy 1 ITM Call and Put	≈0	Positive	Positive	Negative
Short Gut	Sell 1 ITM Call and Put	≈0	Negative	Negative	Positive
Long Strip	Buy 1 ATM Call and Buy 2 ATM Puts	Negative	Positive	Positive	Negative
Short Strip	Sell 1 ATM Call and Sell 2 ATM Puts	Positive	Negative	Negative	Positive
Long Strap	Buy 2 ATM Calls and Buy 1 ATM Put	Positive	Positive	Positive	Negative
Short Strap	Sell 2 ATM Calls and Sell 1 ATM Put	Negative	Negative	Negative	Positive
Long Call Butterfly	Buy 1 ITM Call, Sell 2 ATM Calls and Buy 1 OTM Call	≈0	Negative	Negative	Positive
Short Call Butterfly	Sell 1 ITM Call, Buy2 ATM Calls and Sell 1 OTM Call	≈0	Positive	Positive	Negative
Long Put Butterfly	Buy 1 ITM Put, Sell 2 ATM Puts and Buy 1 OTM Put	≈0	Negative	Negative	Positive
Short Put Butterfly	Sell 1 ITM Put, Buy 2 ATM Puts and Sell 1 OTM Put	≈0	Positive	Positive	Negative
Long Iron Butterfly	Long Straddle and Short Strangle	≈0	Negative	Negative	Positive
Short Iron Butterfly	Short Straddle and Long Strangle	≈0	Positive	Positive	Negative

Table 2
Return calculation for naked positions.

Position	Return for Buy-sell before Maturity	Return for Held to Maturity
Long Call	$\frac{C_{t+n}-C_t}{C_t} - r_n * \frac{n}{360}$	$\frac{Max(0,S_{t+n}-K)-C_t}{C_t} - r_n * \frac{n}{360}$
Short Call	$-\frac{C_{t+n}-C_t}{C_t} + r_n * \frac{n}{360}$	$-\frac{Max(0,S_{t+n}-K)-C_t}{C_t} + r_n * \frac{n}{360}$
Long Put	$\frac{P_{t+n}-P_t}{P_t} - r_n * \frac{n}{360}$	$\frac{Max(0,K-S_{t+n})-P_t}{P_t} - r_n * \frac{n}{360}$
Short Put	$-\frac{P_{t+n}-P_t}{P_t} + r_n * \frac{n}{360}$	$-\frac{Max(0,K-S_{t+n})-P_t}{P_t} + r_n * \frac{n}{360}$

the formula where $C \geq \max(0, S - Ke^{-(r-\delta)t})$ is violated or for put options if the formula where $P \geq \max(0, Ke^{-(r-\delta)t} - S)$ is violated are removed. Secondly, option observations are also removed where the bid price is lower than the ask price and where the bid price is equal to zero. Thirdly, options with spreads lower than the minimum tick size are excluded.[2] Fourthly, options that have no open interest rate are also excluded. The screening process is in place to reduce the recording errors to its minimum level.

2.2. Volatility trading strategies

The option strategies employed in this paper are volatility trading strategies whose value increases when volatility increases and vice versa. These include both long and short straddles, strangles, guts, strips and straps as well as butterflies. Table 1 lists the strategies along with their Greek exposures.

The first two strategies are benchmark strategies: buy-and-hold the market, i.e. a long position in the Standard & Poor's Depositary Receipts (SPDR) S&P 500 ETF Trust (SPY), and a short 10% OTM put. A straddle involves buying an ATM[3] call and an ATM put with the same strike price and expiration date. A strangle differs from the straddle in that both the call and the put are bought OTM with the same expiration but different strike prices. A gut is similar to the strangle but both options are bought ITM. Both a strip and a strap are variations to the straddle, with the former consisting of a long position in a call and two puts with the same strike price and expiration date and the latter consisting of a long position in two calls and a put with the same strike price and expiration date. Finally, a butterfly involves positions in options with three different strike prices.

All strategies are held for three different target maturities, including buying options with 30 days to maturity and holding to maturity, buying options with 60 days to maturity and holding to maturity, and buying options 45 days to maturity and selling approximately 15 days to maturity.[4] Comparing the performance of volatility trading with different maturities gives a good indication of the best way to trade these assets.

In order to test whether volatility trading is profitable, we assume that the strategies are zero-cost so that the initial cost incurred is funded by borrowing at the risk-free rate, the US Generic Government one-month-yield index. For a long position, investors borrow the money for the initial trade and pay the risk-free rate as the cost for borrowing whereas for a short position, investors gain the risk-free rate over the life time of the option. The calculation of returns for naked call and put positions is presented in Table 2 and the payoffs for

[2] For options trading under $3, the minimum tick size is $0.05 whereas for those trading above $3, the minimum tick size is $0.10, as specified by the CBOE.
[3] Options are allowed to vary by 2.5% of their moneyness targets.
[4] The approach to buy options with 60 days before maturity is most widely used in the literature (Carverhill, Cheuk, & Dyrting, 2009; Coval & Shumway, 2001) while that to buy options 45 days but sold 15 days before maturity is similar to the approach used by Santa-Clara and Saretto (2009).

Table 3
Profits for volatility trading strategies before trading frictions: 2002–2007

Strategy	Mean (%)			Standard Deviation (%)			Sharpe Ratio			]Skewness			Kurtosis		
	30days[a]	60days[b]	45days[c]	30days	60days	45days	30days	60days	45days	30days	60days	45days	30days	60days	45days
Long SPX	0.46	0.92	0.46	3.41	4.83	3.41	0.13	0.19	0.13	−0.553	−0.553	−0.553	4.324	4.324	4.324
Short 10% OTM Put	90.23	79.51	61.18	59.10	177.63	67.44	1.53	0.45	0.91	−5.707	−8.307	−3.649	33.585	70.014	17.814
Long Straddle	−9.38	−22.35	−18.49	64.69	58.14	27.62	−0.15	−0.38	−0.67	1.031	1.119	0.715	3.912	4.664	2.446
Short Straddle	9.38	22.35	18.49	64.69	58.14	27.62	0.15	0.38	0.67	−1.031	−1.119	−0.715	3.912	4.664	2.446
Straddle-Mean Reversion[d]	−0.96	6.77	9.02	65.37	61.97	32.04	−0.02	0.11	0.28	−0.526	0.165	−0.442	3.265	2.839	1.916
Long 5% Strangle	−51.72	−55.84	−48.04	150.54	99.96	54.67	−0.34	−0.56	−0.88	3.902	2.711	2.403	19.682	10.648	10.320
Short 5% Strangle	51.72	55.84	48.04	150.54	99.96	54.67	0.34	0.56	0.88	−3.902	−2.711	−2.403	19.682	10.648	10.320
Short 10% Strangle	90.81	83.99	63.88	48.79	132.47	40.95	1.86	0.63	1.56	−4.963	−7.875	−2.790	25.669	63.015	11.643
Long 5% Gut	−2.88	−8.23	−5.80	12.88	18.17	9.36	−0.22	−0.45	−0.62	1.876	2.475	0.580	8.723	14.311	4.739
Short 5% Gut	2.88	8.23	5.80	12.88	18.17	9.36	0.22	0.45	0.62	−1.876	−2.475	−0.580	8.723	14.311	4.739
Long Strip	−11.43	−26.37	−20.99	85.03	67.96	36.04	−0.13	−0.39	−0.58	1.745	2.272	1.506	5.751	10.960	4.632
Short Strip	11.43	26.37	20.99	85.03	67.96	36.04	0.13	0.39	0.58	−1.745	−2.272	−1.506	5.751	10.960	4.632
Long Strap	−7.67	−18.36	−16.25	62.35	65.06	36.87	−0.12	−0.28	−0.44	0.864	0.976	1.080	3.938	3.227	3.229
Short Strap	7.67	18.36	16.25	62.35	65.06	36.87	0.12	0.28	0.44	−0.864	−0.976	−1.080	3.938	3.227	3.229
Long 10% Call Butterfly	3.21	8.40	8.94	45.20	61.89	28.47	0.07	0.14	0.31	−0.329	−0.483	−0.741	4.295	3.236	4.198
Short 10% Call Butterfly	−3.21	−8.40	−8.94	45.20	61.89	28.47	−0.07	−0.14	−0.31	0.329	0.483	0.741	4.295	3.236	4.198
Long 10% Put Butterfly	1.87	39.55	12.79	45.74	88.69	34.76	0.04	0.45	0.37	−1.037	0.484	−0.174	4.082	2.994	2.813
Short 10% Put Butterfly	−1.87	−39.55	−12.79	45.74	88.69	34.76	−0.04	−0.45	−0.37	1.037	−0.484	0.174	4.082	2.994	2.813
Long Iron Butterfly	11.87	12.64	15.63	62.95	58.44	26.50	0.19	0.22	0.59	−0.914	−0.404	−0.600	3.219	2.311	2.043
Short Iron Butterfly	−11.87	−12.64	−15.63	62.95	58.44	26.50	−0.19	−0.22	−0.59	0.914	0.404	0.600	3.219	2.311	2.043

Note:
[a] Options are bought with 30 days to maturity and are held to maturity.
[b] Options are bought with 60 days to maturity and are held to maturity.
[c] Options are bought with 45 days to maturity and are sold 15 days before maturity.
[d] To determine the return for the straddle-mean reversion strategy, we use the approach similar to Goyal and Saretto (2009) who calculate realized volatility using the past realized daily volatility over the past 12 months and implied volatility by the average implied volatility of the ATM call and put. All returns are calculated using mid-prices of options. The long SPX and the short 10% OTM put are benchmark strategies. The risk-free rate used to calculate Sharpe ratios is the US Generic Government one month yield index. For the target maturity of 60 days, all values are displayed for 2 months while for others, values are displayed only for one month.

Table 4
Profits for volatility trading strategies before trading frictions: 2008–2013

Strategy	Mean (%)			Standard Deviation (%)			Sharpe Ratio			Skewness			Kurtosis		
	30days[a]	60days[b]	45days[c]	30days	60days	45days	30days	60days	45days	30days	60days	45days	30days	60days	45days
Long SPX	0.63	1.26	0.63	5.15	7.29	5.15	0.12	0.17	0.12	−0.739	−0.739	−0.739	3.857	3.857	3.857
Short 10% OTM Put	34.70	45.69	27.81	356.18	291.40	183.45	0.10	0.16	0.15	−6.539	−5.979	−4.000	47.624	38.752	19.565
Long Straddle	−4.97	−10.22	−9.80	78.72	73.65	41.82	−0.06	−0.14	−0.23	2.104	1.581	1.910	9.239	6.696	7.255
Short Straddle	4.97	10.22	9.80	78.72	73.65	41.82	0.06	0.14	0.23	−2.104	−1.581	−1.910	9.239	6.696	7.255
Straddle-Mean Reversion[d]	−1.76	1.81	1.66	78.86	74.34	42.93	−0.02	0.02	0.04	−0.540	−1.358	−0.321	8.615	5.842	5.252
Long 5% Strangle	−29.84	−25.92	−21.11	246.99	125.45	103.06	−0.12	−0.21	−0.21	4.866	2.561	2.874	27.144	10.901	12.207
Short 5% Strangle	29.84	25.92	21.11	246.99	125.45	103.06	0.12	0.21	0.21	−4.866	−2.561	−2.874	27.144	10.901	12.207
Short 10% Strangle	34.96	55.11	25.71	345.29	205.70	157.07	0.10	0.27	0.16	−6.439	−5.990	−3.503	46.151	40.085	15.440
Long 5% Gut	−5.34	−5.44	−3.84	19.33	32.31	16.30	−0.28	−0.17	−0.24	2.937	2.990	1.243	13.906	15.466	4.509
Short 5% Gut	5.34	5.44	3.84	19.33	32.31	16.30	0.28	0.17	0.24	−2.937	−2.990	−1.243	13.906	15.446	4.509
Long Strip	−11.88	−16.46	−13.38	100.90	94.14	59.59	−0.12	−0.18	−0.23	2.860	2.729	2.426	12.369	11.526	9.018
Short Strip	11.88	16.46	13.38	100.90	94.14	59.59	0.12	0.18	0.23	−2.860	−2.729	−2.426	12.369	11.526	9.018
Long Strap	1.46	−3.58	−5.91	69.31	71.00	41.54	−0.02	−0.05	−0.14	0.710	0.458	1.160	3.380	1.981	4.627
Short Strap	−1.46	3.58	5.91	69.31	71.00	41.54	0.02	0.05	0.14	−0.710	−0.458	−1.160	3.380	1.981	4.627
Long 10% Call Butterfly	6.28	4.38	4.44	53.36	81.58	37.76	0.12	0.05	0.12	0.516	0.494	−0.432	4.916	3.378	2.716
Short 10% Call Butterfly	−6.28	−4.38	−4.44	53.36	81.58	37.76	−0.12	−0.05	−0.12	−0.516	−0.494	0.432	4.916	3.378	2.716
Long 10% Put Butterfly	11.60	11.58	13.27	65.07	113.12	62.92	0.18	0.10	0.21	−0.012	0.910	−0.096	2.869	3.507	3.000
Short 10% Put Butterfly	−11.60	−11.58	−13.27	65.07	113.12	62.92	−0.18	−0.10	−0.21	0.012	−0.910	0.096	2.869	3.507	3.000
Long Iron Butterfly	0.10	2.45	7.02	68.15	61.87	32.66	0.00	0.04	0.22	−1.167	0.156	−1.626	5.276	1.652	6.626
Short Iron Butterfly	−0.10	−2.45	−7.02	68.15	61.87	32.66	−0.00	−0.04	−0.22	1.167	−0.156	1.626	5.276	1.652	6.626

Note:

[a] Options are bought with 30 days to maturity and are held to maturity.

[b] Options are bought with 60 days to maturity and are held to maturity.

[c] Options are bought with 45 days to maturity and are sold 15 days before maturity.

[d] To determine the return for the straddle-mean reversion strategy, we use the approach similar to Goyal and Saretto (2009) who calculate realized volatility using the past realized daily volatility over the past 12 months and implied volatility by the average implied volatility of the ATM call and put. All returns are calculated using mid-prices of options. The long SPX and the short 10% OTM put are benchmark strategies. The risk-free rate used to calculate Sharpe ratios is the US Generic Government one month yield index. For the target maturity of 60 days, all values are displayed for 2 months while for others, values are displayed only for one month.

Table 5
Statistical evidence on sharpe ratios before trading frictions: Volatility trading strategies against benchmarks: 2002–2007 versus 2008–2013.

Strategy	Sharpe Ratio (2002–2007)						Sharpe Ratio (2008–2013)					
	Against Long SPX			Against Short 10% OTM Put			Against Long SPX			Against Short 10% OTM Put		
	30days[a]	60days[b]	45days[c]	30days[a]	60days[b]	45days[c]	30days[a]	60days[b]	45days[c]	30days[a]	60days[b]	45days[c]
Long Straddle	−0.28(0.01)	−0.57(0.00)	−0.80(0.00)	−1.68(0.00)	−0.83(0.00)	−1.58(0.00)	−0.18(0.05)	−0.31(0.00)	−0.35(0.00)	−1.16(0.00)	−0.83(0.00)	−1.58(0.00)
Short Straddle	**0.02**(0.15)	**0.19**(0.05)	**0.54**(0.00)	−1.38(0.00)	−0.07(0.10)	−0.24(0.01)	−0.06(0.10)	−0.03(0.15)	**0.11**(0.05)	−0.04(0.15) -	−0.06(0.10)	−0.24(0.05)
Straddle-Mean Reversion[d]	−0.15(0.05)	−0.08(0.10)	**0.15**(0.05)	−1.55(0.00)	−0.34(0.00)	−0.63(0.00)	−0.14(0.05)	−0.15(0.05)	−0.08(0.10)	−0.12(0.05)	−0.34(0.00)	−0.39(0.00)
Long 5% Strangle	−0.47(0.00)	−0.75(0.00)	−1.01(0.00)	−1.87(0.00)	−1.01(0.00)	−1.79(0.00)	−0.24(0.01)	−0.38(0.00)	−0.33(0.00)	−0.22(0.01)	−1.01(0.00)	−1.79(0.00)
Short 5% Strangle	**0.21**(0.01)	**0.37**(0.00)	**0.75**(0.00)	−1.19(0.00)	**0.11**(0.05)	−0.03(0.15)	−0.00(0.20)	**0.04**(0.15)	**0.09**(0.10)	**0.02**(0.15)	**0.11**(0.05)	−0.03(0.15)
Short 10% Strangle	**1.73**(0.00)	**0.44**(0.00)	**1.43**(0.00)	**0.33**(0.00)	**0.18**(0.05)	**0.65**(0.00)	−0.02(0.17)	**0.10**(0.10)	**0.04**(0.15)	**0.00**(0.20)	**0.19**(0.05)	**0.65**(0.00)
Long 5% Gut	−0.35(0.00)	−0.64(0.00)	−0.75(0.00)	−1.75(0.00)	−0.90(0.00)	−1.53(0.00)	−0.40(0.00)	−0.34(0.00)	−0.36(0.00)	−0.38(0.00)	−0.90(0.00)	−1.53(0.00)
Short 5% Gut	**0.09**(0.10)	**0.26**(0.01)	**0.49**(0.00)	−1.31(0.00)	**0.01**(0.15)	−0.29(0.01)	**0.16**(0.05)	−0.00(0.20)	**0.12**(0.05)	**0.18**(0.05)	−0.01(0.15)	−0.28(0.01)
Long Strip	−0.26(0.01)	−0.58(0.00)	−0.71(0.00)	−1.66(0.00)	−0.84(0.00)	−1.49(0.00)	−0.24(0.01)	−0.35(0.00)	−0.35(0.00)	−0.22(0.01)	−0.84(0.00)	−1.49(0.00)
Short Strip	**0.00**(0.20)	**0.20**(0.05)	**0.45**(0.00)	−1.40(0.00)	−0.06(0.10)	−0.33(0.00)	−0.00(0.20)	**0.01**(0.15)	**0.11**(0.05)	**0.02**(0.15)	−0.06(0.10)	−0.32(0.01)
Long Strap	−0.25(0.01)	−0.47(0.00)	−0.57(0.00)	−1.65(0.00)	−0.73(0.00)	−1.35(0.00)	−0.14(0.05)	−0.22(0.01)	−0.26(0.01)	−0.12(0.05)	−0.73(0.00)	−1.35(0.00)
Short Strap	−0.01(0.15)	**0.09**(0.10)	**0.31**(0.00)	−1.41(0.00)	−0.17(0.05)	−0.47(0.00)	−0.12(0.10)	−0.12(0.05)	**0.02**(0.15)	−0.10(0.10)	−0.17(0.05)	−0.50(0.01)
Long 10% Call Butterfly	−0.06(0.10)	−0.05(0.10)	**0.18**(0.05)	−1.46(0.00)	−0.31(0.00)	−0.60(0.00)	−0.00(0.20)	−0.12(0.05)	**0.00**(0.20)	−1.46(0.00)	−0.31(0.00)	−0.59(0.01)
Short 10% Call Butterfly	−0.20(0.01)	−0.33(0.00)	−0.44(0.00)	−1.60(0.00)	−0.59(0.00)	−1.22(0.00)	−0.24(0.01)	−0.22(0.01)	−0.24(0.01)	−1.60(0.00)	−0.58(0.00)	−1.22(0.00)
Long 10% Put Butterfly	−0.09(0.10)	**0.26**(0.01)	**0.24**(0.01)	−1.49(0.00)	−0.00(0.20)	−0.54(0.00)	**0.06** (0.00)	−0.07(0.10)	**0.09**(0.10)	−1.49(0.00)	−0.00(0.23)	−0.54(0.01)
Short 10% Put Butterfly	−0.17(0.05)	−0.64(0.00)	−0.50(0.00)	−1.57(0.00)	−0.90(0.00)	−1.28(0.00)	−0.03(0.15)	−0.27(0.01)	−0.33(0.00)	−1.57(0.00)	−0.89(0.00)	−1.28(0.00)
Long Iron Butterfly	**0.06**(0.10)	**0.03**(0.15)	**0.46**(0.00)	−1.34(0.00)	−0.23(0.01)	−0.32(0.00)	−0.12(0.05)	−0.13(0.05)	**0.09**(0.10)	−1.34(0.00)	−0.23(0.01)	−0.32(0.01)
Short Iron Butterfly	−0.32(0.00)	−0.41(0.00)	−0.72(0.00)	−1.72(0.00)	**0.67**(0.00)	−1.50(0.00)	−0.12(0.05)	−0.21(0.01)	−0.34(0.00)	−1.72(0.00)	−0.66(0.00)	−1.50(0.00)

The values in bold are the cases where the Sharpe ratios of trading strategies are larger than the benchmarks.
Note:
[a] Options are bought with 30 days to maturity and are held to maturity.
[b] Options are bought with 60 days to maturity and are held to maturity.
[c] Options are bought with 45 days to maturity and are sold 15 days before maturity. *P*-values in the bracket are calculated using the method developed by Memmel (2003) and are reported to the nearest confidence level.
[d] To determine the return for the straddle-mean reversion strategy, we use the approach similar to Goyal and Saretto (2009) who calculate realized volatility using the past realized daily volatility over the past 12 months and implied volatility by the average implied volatility of the ATM call and put. All returns are calculated using actual bid-ask prices of options.

Table 6
Profits for short volatility trading strategies after bid-ask spreads: 2002–2007 versus 2008–2013.

Strategy	2002–2007						2008–2013					
	Mean (%)			Sharpe Ratio			Mean (%)			Sharpe Ratio		
	30days[a]	60days[b]	45days[c]	30days	60days	45days	30days	60days	45days	30days	60days	45days
Long SPX	0.46	0.92	0.46	0.13	0.19	0.13	0.63	1.26	0.63	0.12	0.17	0.12
Short 10% OTM Put	89.47	77.67	46.36	1.41	0.40	0.48	22.57	41.60	10.94	0.05	0.13	0.05
Short Straddle	6.00	19.72	12.76	0.09	0.33	0.44	0.80	7.06	3.46	0.01	0.09	0.08
Short 5% Strangle	47.16	53.04	39.19	0.29	0.50	0.62	23.45	41.60	9.99	0.09	0.13	0.09
Short 10% Strangle	89.86	82.11	49.20	1.67	0.56	1.01	21.16	51.07	5.21	0.05	0.23	0.03
Short 5% Gut	1.24	6.78	2.74	0.10	0.37	0.29	3.15	3.54	−0.02	0.16	0.11	−0.00
Short Strip	8.13	23.82	15.37	0.09	0.34	0.40	8.07	13.45	7.23	0.08	0.14	0.11
Short Strap	4.24	15.61	10.42	0.07	0.23	0.27	−5.94	0.26	−0.62	−0.08	0.00	−0.01
Short 10% Call Butterfly	−7.97	−16.08	−20.91	−0.16	−0.24	−0.64	−18.97	−19.31	−17.27	−0.30	−0.18	−0.14
Short 10% Put Butterfly	−6.96	−57.99	−28.37	−0.14	−0.53	−0.69	−23.24	−44.25	−39.88	−0.28	−0.24	−0.52
Short Iron Butterfly	−15.95	−16.80	−23.08	−0.27	−0.30	−0.92	−6.27	−8.09	−16.48	−0.10	−0.14	−0.56

Note:
The long SPX index and the short 10% OTM put are benchmark strategies. The risk-free rate used to calculate Sharpe ratios is the US Generic Government one month yield index. For the target maturity of 60 days, all values are displayed for 2 months while for others, values are displayed for only one month.
[a] Options are bought with 30 days to maturity and are held to maturity.
[b] Options are bought with 60 days to maturity and are held to maturity.
[c] Options are bought with 45 days to maturity and are sold 15 days before maturity.

all trading strategies can be easily determined by utilizing the returns of individual option components.[5] where C_{t+n} = price of call option at last trading date $t+n$; C_t = price of call option at trading date t; P_{t+n} = price of put option at last trading date $t+n$; P_t = price of put option at trading date t; r_n = annualized risk-free rate; n = holding period; S_{t+n} = stock price at maturity date $t+n$; K = strike price of option.

We then use historical data to compare the performance of the trading strategies to both the buy-and-hold and the short 10% OTM put benchmarks and label it as a baseline study. However, options are affected by trading frictions, such as bid-ask spreads. Therefore, rather than using mid-prices of options, we consider actual bid-ask prices when investors sell and purchase options. Furthermore, we also measure the impact of margins as to the ability of investors participating in the market on realized profits of the strategies by both the margin haircut ratio and the maximum cumulative margin call. The margin haircut ratio is given as:

$$\frac{(M_0 - I)}{I} \tag{1}$$

where M_0 is the margin at the beginning at each trade and I is the initial capital inflow using options prices with bid-ask spreads incorporated.[6] The reverse of the ratio can be interpreted as the maximum amount that investors can invest in a position as a percentage of their wealth.

In contrast, the maximum cumulative margin call estimates how often the minimum maintenance margin is violated and is calculated as the difference between the maximum margin requirement and the initial margin requirement as a percentage of the initial capital inflow. In this paper, the minimum of the cumulative margin call must be 1% of the initial capital inflow. Otherwise, it is deemed as unimportant to trading strategies and is not included as having a margin call. In addition, there must be 10 days of observations for options in use when held for 30 days and 20 days of observations for options when held for 60 days.

3. Empirical results

3.1. Baseline study

Tables 3 and 4 report the profits for all trading strategies in the two sample periods without trading frictions. Table 5 provides further evidence on how differently the volatility trading strategies perform from the benchmarks by showing both the difference in Sharpe

[5] For example, the return for a long straddle position, where the position is sold before its maturity with an initial cost of $C_t + P_t$, is $\frac{C_{t+n} - C_t + P_{t+n} - P_t}{C_t + P_t} - r_n * \frac{n}{360}$ whereas for a long straddle position held to maturity, its return is calculated as $\frac{\max(0, S_{t+n} - K) - C_t + \max(0, K - S_{t+n}) - P_t}{C_t + P_t} - r_n * \frac{n}{360}$.

[6] The initial requirement as specified by the CBOE for naked short positions are given as:

$$\text{Call Margin} = M_t = \max(C_t + XS_t - (K - S_t) | \mathrm{K} > S_t), C_t + YS_t)$$

$$\text{Put Margin} = M_t = \max(P_t + XS_t - (S_t - K) | S_t > K), P_t + YK)$$

where X and Y are 15% and 10%, respectively for SPX contracts. t is the trading date and the initial margin requirement is derived using the two equations when $t = 0$. For option strategies that are constructed with more than one option, such as the straddle and strangle, the margin requirement is the greater of the call or put requirement plus the proceeds of the other side. For strategies that trade a spread, such as the butterflies, the margin requirement is the difference between the spread in the exercise prices.

Table 7
Statistical evidence on sharpe ratios after trading frictions volatility trading strategies against benchmarks: 2002–2007 versus 2008–2013.

Strategy	Sharpe Ratio (2002–2007)						Sharpe Ratio (2008–2013)					
	Against Long SPX			Against Short 10% OTM Put			Against Long SPX			Against Short 10% OTM Put		
	30days[a]	60days[b]	45days[c]	30days[a]	60days[b]	45days[c]	30days[a]	60days[b]	45days[c]	30days[a]	60days[b]	45days[c]
Short Straddle	−0.04(0.15)	**0.14**(0.05)	**0.31**(0.00)	−1.32(0.00)	−0.07(0.10)	−0.04(0.15)	−0.11(0.10)	−0.08(0.10)	−0.04(0.15)	−0.04(0.15) -	−0.04(0.15)	**0.03**(0.15)
Short 5% Strangle	**0.16**(0.05)	**0.31**(0.00)	**0.49**(0.00)	−1.12(0.00)	**0.10**(0.10)	**0.14** (0.05)	−0.03(0.15)	−0.04 (0.10)	−0.03 (0.15)	**0.04**(0.15)	**0.00**(0.20)	**0.04**(0.15)
Short 10% Strangle	**1.54**(0.00)	**0.37**(0.00)	**0.88**(0.00)	**0.26**(0.01)	**0.16**(0.05)	**0.53**(0.00)	−0.07(0.10)	**0.06**(0.10)	−0.09 (0.10)	**0.00**(0.20)	**0.10**(0.10)	−0.02(0.15)
Short 5% Gut	−0.03(0.15)	**0.18**(0.05)	**0.16**(0.05)	−1.31(0.00)	−0.03 (0.15)	−0.19(0.05)	**0.04**(0.15)	−0.06(0.10)	−0.12(0.05)	**0.11**(0.05)	−0.02(0.15)	−0.05(0.10)
Short Strip	−0.04 (0.15)	**0.15**(0.05)	**0.27**(0.01)	−1.32(0.00)	−0.06(0.10)	−0.08(0.10)	−0.04(0.15)	−0.03(0.15)	−0.01(0.15)	**0.03**(0.15)	**0.01**(0.15)	**0.06**(0.10)
Short Strap	−0.06(0.10)	**0.04**(0.15)	**0.14**(0.05)	−1.34(0.00)	−0.17(0.05)	−0.21(0.01)	−0.20(0.01)	−0.17(0.05)	−0.13 (0.15)	−0.13(0.05)	−0.13(0.05)	−0.06(0.10)
Short 10% Call Butterfly	−0.29(0.01)	−0.43(0.00)	−0.77(0.00)	−1.57(0.00)	−0.64(0.00)	−1.12(0.00)	−0.42(0.00)	−0.35(0.00)	−0.26(0.01)	−0.35(0.00)	−0.31(0.00)	−0.19(0.05)
Short 10% Put Butterfly	−0.27(0.01)	−0.72(0.00)	−0.82(0.00)	−1.55(0.00)	−0.93(0.00)	−1.17(0.00)	−0.40(0.00)	−0.41(0.00)	−0.64(0.00)	−0.33(0.00)	−0.37(0.00)	−0.57(0.00)
Short Iron Butterfly	−0.40(0.00)	−0.49(0.00)	−1.05(0.00)	−1.68(0.00)	−0.70(0.00)	−1.40(0.00)	−0.22(0.01)	−0.31(0.00)	−0.68(0.00)	−0.15(0.05)	−0.27(0.05)	−0.61(0.00)

The values in bold are the cases where the Sharpe ratios of trading strategies are larger than the benchmarks.
Note:
[a] Options are bought with 30 days to maturity and are held to maturity.
[b] Options are bought with 60 days to maturity and are held to maturity.
[c] Options are bought with 45 days to maturity and are sold 15 days before maturity. *P*-values in the bracket are calculated using the method developed by Memmel (2003) and are reported to the nearest confidence level.

Table 8
Margin haircut ratios for short volatility trading strategies: 2002–2007 versus 2008–201.

Strategy	2002–2007											
	Mean			Standard Deviation			Minimum			Maximum		
	30days[a]	60days[b]	45days[c]	30days	60days	45days	30days	60days	45days	30days	60days	45days
Short 10% OTM Put	140.69	35.93	58.25	147.42	28.22	46.35	8.39	4.54	6.30	842.17	127.75	190.62
Short Straddle	6.09	4.35	4.92	1.55	0.98	1.16	2.92	2.38	2.64	8.75	6.06	6.92
Short 5% Strangle	31.79	10.63	15.21	24.52	6.46	9.42	3.36	2.58	3.14	94.59	27.05	41.30
Short 10% Strangle	107.55	30.52	49.88	117.43	25.30	41.36	6.83	3.32	4.34	702.88	118.01	172.35
Short 5% Gut	2.49	2.35	2.40	0.17	0.19	0.17	2.08	1.86	1.90	2.85	2.77	2.74
Short Strip	7.86	5.52	6.29	2.21	1.42	1.63	3.50	2.81	3.18	11.71	8.15	9.19
Short Strap	7.66	5.33	6.10	1.97	1.25	1.48	3.53	2.81	3.12	11.10	7.44	8.65
Short 10% Call Butterfly	1.71	2.18	2.01	0.49	0.77	0.74	1.28	1.48	1.43	3.54	6.15	5.17
Short 10% Put Butterfly	1.73	2.76	2.28	0.43	1.23	0.82	1.27	1.44	1.33	3.14	6.58	5.03
Short Iron Butterfly	3.39	2.45	2.43	0.93	0.52	1.47	1.71	1.49	1.44	5.58	3.50	9.44
	2008–2013											
Short 10% OTM Put	55.92	16.80	25.52	47.28	11.12	18.22	3.26	2.67	3.36	223.07	47.04	80.98
Short Straddle	4.99	3.67	4.09	1.45	0.87	1.02	1.97	1.86	2.04	7.71	5.58	6.09
Short 5% Strangle	15.94	6.56	8.59	11.34	3.64	4.99	2.00	1.79	1.98	46.97	21.55	22.73
Short 10% Strangle	54.63	17.05	26.23	46.94	12.53	19.82	2.38	1.98	2.49	204.39	51.56	87.62
Short 5% Gut	2.38	2.23	2.28	0.18	0.19	0.17	1.76	1.68	1.75	2.68	2.67	2.64
Short Strip	6.32	4.49	5.03	1.90	1.13	1.31	2.28	2.13	2.36	9.86	6.96	7.51
Short Strap	6.37	4.60	5.15	1.95	1.20	1.40	2.26	2.14	2.38	10.09	7.19	8.02
Short 10% Call Butterfly	4.82	2.62	2.43	22.68	1.25	1.47	1.32	1.50	1.44	187.50	8.19	9.44
Short 10% Put Butterfly	5.72	3.76	3.03	13.95	3.05	1.60	1.30	1.78	1.52	125.00	18.92	8.97
Short Iron Butterfly	2.89	2.17	2.39	0.84	0.48	0.59	1.54	1.40	1.42	4.71	3.38	3.63

Note:
[a] Options are bought with 30 days to maturity and are held to maturity.
[b] Options are bought with 60 days to maturity and are held to maturity.
[c] Options are bought with 45 days to maturity and are sold 15 days before maturity. The short 10% OTM put is the benchmark strategy.

ratios and the *p*-values. For positions that are bought 30 days before maturity, it is quite obvious that short volatility outperforms long volatility over both sample periods. The exception includes the strap strategies: in the years before 2008, the long strap generates a negative return while the short strap has a positive return on average. This pattern reverses after the market crisis in 2008.

Short volatility is generally more profitable than long volatility despite the fact that all positions, except for the strip and the strap, have close to zero Deltas or barely have any market risk. This is consistent with previous studies that market risk alone is not sufficient to explain option returns and factors like volatility risk premiums are also found to affect returns (Bakshi & Kapadia, 2003; Cao & Huang, 2007; Constantinides, Jackwerth, & Savov, 2013; Driessen & Maenhout, 2013; Lin & Lin, 2016).

Among all volatility strategies, the short gut is the only one that competes with the buy-and-hold benchmark with statistical significance at the conventional levels on a risk-adjusted basis. Before 2008, the short gut along with the short straddle, short strangles (both 5% and 10%) and the long iron butterfly outperform the market while after 2008 only the performance of both the short gut and the long put butterfly is superior. The advantage of the gut position is attributed to its reasonably high average return and lower volatility as the position is constructed with more expensive ITM options so that it is not exposed so heavily to market movements against investors (if any) as a position composed of OTM options.

When the short 10% OTM put is used as a benchmark, the superior strategy changes to the short 10% strangle which earns the highest monthly average returns also with high volatility. In the years preceding 2008, it comfortably beats the benchmark with a Sharpe ratio of 1.86. From 2008 onwards, its standard deviation rises sharply from 48.79% to 345.29%, which greatly affects the value of the Sharpe ratio. However, the strategy is still comparable with the benchmark on a risk-adjusted basis.

It is well known that option returns are characterized by skewness and leptokurtosis and this is evident for almost all trading strategies over both sample periods: the skewness and the kurtosis values for most strategies exceed those of the normal distribution. As expected, the risk is much higher in the after-crisis years for most strategies. The high moment values for the straddle position increase dramatically, with the values being more than doubling the pre-crisis sample values. Strategies like the three butterflies that lock in limited profits or losses reduce these high moments substantially and therefore may serve as an attractive feature to investors in this sense.

The results for positions that are bought 60 days before maturity are largely similar with a few minor differences. For example, the short gut no longer consistently beats the buy-and-hold benchmark across both sample periods. The short strangles (both 5% and 10%) now have superior performance to both benchmarks with statistical significance on a risk-adjusted basis in most cases. Over a 60 day holding period, the butterflies have an enhanced performance. The Sharpe ratio of the long put (the long iron) butterfly is 0.45(0.22), (significantly) higher than that of an investment in the market index before the crisis. Furthermore, the long put butterfly almost competes with the short position in a 10% OTM put during the same period.

In contrast to both holding 30 days and 60 days to maturity, the Sharpe ratios for engaging in volatility trading 45 days to maturity and exiting the position 15 days before expiration tend to be much higher. This suggests that selling options before they expire is a better play on volatility trading. In addition, there are now more strategies that outperform the benchmarks with statistical significance on

Table 9
Maximum cumulative margin calls for short volatility trading strategies: 2002–2007 versus 2008–2013.

Strategy	% Called			2002–2007											
				Mean			Standard Deviation			Minimum			Maximum		
	30days[a]	60days[b]	45days[c]	30days[a]	60days[b]	45days[c]	30days	60days	45days	30days	60days	45days	30days	60days	45days
Short 10% OTM Put	64%	77%	71%	5.29	3.11	1.57	14.23	5.83	2.43	0.02	0.01	0.01	80.74	24.21	12.16
Short Straddle	60%	100%	56%	0.38	0.29	0.24	0.37	0.19	0.22	0.02	0.09	0.02	1.53	0.53	0.89
Short 5% Strangle	100%	94%	97%	5.65	3.09	2.98	4.70	2.53	2.69	0.08	0.07	0.02	20.76	13.87	11.16
Short 10% Strangle	61%	76%	70%	1.54	2.32	1.38	2.34	3.51	2.09	0.05	0.06	0.03	11.08	15.11	10.27
Short 5% Gut	47%	68%	54%	0.07	0.13	0.06	0.09	0.17	0.07	0.01	0.01	0.01	0.41	0.70	0.42
Short Strip	61%	63%	82%	0.44	0.41	0.26	0.48	0.54	0.30	0.02	0.03	0.01	2.34	2.83	1.71
Short Strap	66%	76%	75%	0.51	0.53	0.29	0.53	0.52	0.24	0.01	0.03	0.01	2.31	2.07	0.92
				2008–2013											
Short 10% OTM Put	54%	72%	65%	6.89	3.81	3.29	14.34	5.90	5.98	0.10	0.08	0.03	69.45	27.62	30.02
Short Straddle	76%	85%	69%	0.38	0.36	0.24	0.37	0.41	0.25	0.02	0.05	0.01	1.77	1.52	1.06
Short 5% Strangle	100%	100%	99%	4.19	2.51	2.44	3.51	1.84	1.79	0.09	0.31	0.04	15.22	7.75	7.20
Short 10% Strangle	65%	86%	80%	1.20	1.56	1.45	1.47	2.55	2.61	0.06	0.03	0.01	8.48	16.78	14.34
Short 5% Gut	57%	74%	64%	0.12	0.16	0.10	0.18	0.20	0.13	0.01	0.01	0.01	0.85	0.93	0.59
Short Strip	56%	73%	64%	0.48	0.45	0.35	0.60	0.64	0.38	0.01	0.01	0.01	2.63	2.89	1.50
Short Strap	77%	77%	75%	0.58	0.58	0.32	0.41	0.43	0.28	0.02	0.06	0.02	2.27	1.77	1.39

Note:
[a] Options are bought with 30 days to maturity and are held to maturity.
[b] Options are bought with 60 days to maturity and are held to maturity.
[c] Options are bought with 45 days to maturity and are sold 15 days before maturity. The short 10% OTM put is the benchmark strategy.

a risk-adjusted basis. In the years before the crisis, almost all short volatility strategies have significantly higher Sharpe ratios than buying-and-holding the market. This also applies to the years after the crisis albeit with the statistical importance greatly reducing.

One of the biggest advantages of closing out the position before maturity lies in the fact that options are sold with time value rather than being held to expiration worthlessly. For all trading strategies, the volatility reduces significantly for both sample periods. For example, the standard deviation of the returns of a straddle position is roughly half of the value when the position is held to maturity.

Among all trading strategies, the short straddle benefits most from selling options before maturity. Its Sharpe ratio increases to a massive 0.67 in the pre-crisis period and to 0.23 in the after-crisis period. Having a high risk-adjusted return in both sample periods helps explain why a straddle is most frequently used by investors in practice when engaging in volatility trading.

Overall, using all information from Tables 3–5, we find that short volatility strategies can earn significant profits in excess of both the buy-and-hold and the short 10% OTM put benchmarks. Among these trading strategies, the short 10% strangle tends to be more consistent, which beats both benchmarks with statistical significance almost across all different sample and holding periods.

3.2. *Effect of bid-ask spreads*

Evaluating the effect of trading frictions is an important issue concerning a trading strategy's success (Liu, 2007). Therefore, we consider bid-ask spreads which have the biggest impact on option trading in this section. To preserve space, Table 6 only reports the means and the Sharpe ratios for all short volatility strategies both in the years preceding and following 2008, which might be of greater interest to investors when making investment decisions. Table 7 provides statistical evidence on how differently the short volatility strategies perform from the benchmarks on a risk-adjusted basis.

For all trading strategies, bid-ask spreads have a negative impact on both average returns and Sharpe ratios. As expected, the spreads more affect positions that are sold before maturity as investors not only need to pay the spreads at the beginning of the trade but also when exiting the trade. For example, comparing Tables 3, 4 and 6, the average monthly return for the short straddle reduces approximately 6% when sold 15 days before maturity, which is much higher than any reduction caused by the position held until maturity. Furthermore, strategies constructed with several options are also more severely affected by the spreads. This particularly applies to the butterflies which are composed of four options. In the years after 2008, no butterflies have positive returns with the target maturities of 45 days and 60 days.

The impact of bid-ask spreads is also evident by comparing the performance of short volatility across sample periods. Before 2008, most strategies earn positive returns with high Sharpe ratios even after the spreads. This is particularly true for both the straddle and the strangle positions when they are sold 15 days before maturity. The only strategy consistently comparable to both the buy-and-hold and the short 10% OTM put benchmarks is the short 10% strangle. In contrast, from 2008 onwards, there is a more severe reduction in profitability caused by the spreads: for almost all strategies, their average returns decrease at a greater rate. The short 10% strangle is one example heavily affected: its average monthly return is 49.20% before the crisis whereas this drops to just above 5% after the crisis when the position is sold 15 days before maturity. This precisely reflects the volatile nature of investing in volatility trading strategies.

Finally, the difference between the Sharpe ratios for most strategies and the benchmarks is significantly reduced after the spreads particularly during the second sample period. For example, the Sharpe ratio generated by the short straddle with the target maturity of 45 days after 2008 is 0.23, higher than 0.12 for the buy-and-hold benchmark. The difference is statistically significant at the 5% level. However, when the spreads are taken into account, the Sharpe ratio reduces to 0.08, becoming smaller than 0.12 for the benchmark.

Overall, the profitability of volatility trading is significantly reduced although not eliminated after the inclusion of bid-ask spreads. Unlike the baseline study, no strategies are able to consistently compete with both benchmarks in all scenarios. This suggests that the seemingly impressive profits of volatility trading as documented in Tables 3–5 may be unattainable given the presence of bid-ask spreads. Profitability is likely to rely on the capability of investors to identify the right strategy and execute at the right time.

3.3. Effect of margin requirements

Margin accounts have an important effect on short positions as when investors take a short position, where losses can exceed the original capital outlay, they must provide extra capital in the form of a margin account. We further consider the impact of margin requirements on short positions. Table 8 shows the margin haircut ratios for all short positions that have an inflow of capital in both sample periods.

The margin haircut ratios are particularly high on the strategies like the short 10% OTM put benchmark and the short strangles (both 5% and 10%). An investor would have to post $149.69 on average for every dollar of options invested in a 10% short put with 30 days to maturity before 2008. In other words, the investor can only use less than 1% (1/149.69) of his wealth in the position, suggesting that the profit from the short put is very difficult to take advantage of. The fact that the haircut ratio is relatively higher for the short put than other strategies de-motivates investment in naked positions. With respect to the short strangles, they use cheap OTM options to construct positions and the computation of the haircut ratios does not consider the likelihood of extreme events, which leads to large values across all holding periods. Interestingly, the haircut ratios are much lower in the years after 2008, with the values being about halving for the strangle positions. The reason for the reduced ratios can be attributed to the higher implied volatility and subsequently the higher option prices so that the investor is in a better position to cover the margin account using the proceeds from the sale of options.

It is also apparent that for most trading strategies, there is a negative relationship between the target maturity and the haircut ratio. With a longer time to maturity, short positions can help investors receive higher proceeds from the sale of options which in turn contributes to the margin account. For example, the proceeds from the short straddle are $4614 (1 contract has a $100 multiplier) for a 30 day holding period and $6828 for a 60 day holding period on average.[7]

The only exception for the rule of lower haircut ratios with longer time to maturities is the short call and the short put butterfly strategies. This is because the proceeds received are lower over a long time period: the proceeds from a short call butterfly decrease from $7070 in a 30 day period to $5850 in a 60 day period whereas those from a short put butterfly drop from $6230 to $4190.

Among all strategies, the short gut tends to be most stable when executing volatility trading, with a reasonably small and low volatile haircut ratio compared to other strategies across both sample periods. The highest maximum haircut ratio is 2.85 for the position held 30 days to maturity, with investors being able to use 35% of their wealth in the short gut. This haircut ratio tends to be high as the returns for the strategy are not volatile at all as shown in Tables 3 and 4

In addition to the margin haircut ratio, we also consider the maximum cumulative margin call as described in Section 2.2 for short volatility in Table 9. To be noted, the butterfly positions do not have an exposure to margin calls as their margin accounts are calculated by the spreads in exercise prices, which stay constant throughout the periods studied and therefore are not included in the table.

Consistent with the results shown by the margin haircut ratio, volatility trading strategies that are cheap to construct face severe liquidation problems. For the short 5% OTM strangle, it is very difficult for an investor to keep the position open. As displayed in Table 8, the haircut ratio is $31.79 for a holding period of 30 days before 2008, suggesting that the investor could invest approximately 3.15% of his wealth in the short strangle position. However, if he chooses to use the fund available, he would be forced to liquidate the position 100% of the time. This severely affects the profitability of the strangle position which usually has a high average return. In contrast, the short 10% OTM strangle has a smaller margin call but a higher haircut ratio, indicating that the position is less sensitive to small market movements.

Compared to the short strangle positions, the short straddle has much lower maximum cumulative margin calls, with an average value less than 0.04 for all holding periods. When the effect of margin account is included, the short straddle seems more attractive to investors than the short strangles for the following reasons. Firstly, more funds can be used in the position rather than being locked in the margin account. Secondly, the margin calls are less severe so that the forced liquidation is not as regular as the short strangles. For

[7] The average (quoted) initial capital outflow (inflow) for executing strategies is presented as follows.

Strategy	30days		60days		45days	
	Mid[1]	Bid to Ask[2]	Mid	Bid to Ask	Mid	Bid to Ask
Short 10% OTM Put	−4.07	−3.59	−9.19	−8.53	−6.51	−5.95
Short Straddle	−48.05	−46.14	−70.53	−68.28	−60.72	−58.63
Short 5% Strangle	−13.42	−12.31	−28.27	−26.59	−21.15	−19.85
Short 10% Strangle	−5.85	−5.09	−12.88	−11.80	−9.13	−8.21
Short 5% Gut	−132.66	−130.05	−148.60	−145.97	−142.10	−139.50
Short Strip	−72.31	−69.43	−105.73	−102.34	−91.00	−87.87
Short Strap	−71.84	−68.98	−105.86	−102.50	−91.15	−88.02
Short10% Call Butterfly	−74.35	−70.70	−62.49	−58.50	−67.46	−63.58
Short 10% Put Butterfly	−66.56	−62.30	−46.69	−41.90	−54.26	−49.83
Short Iron Butterfly	44.47	47.18	59.20	62.58	53.21	50.13

Note: [1] Middle price. [2] Incorporating bid-ask price. The short 10% OTM put is the benchmark strategy.

example, using the information from both Tables 8 and 9, investors could have invested up to 15% (1/(6.09 + 0.38)) of their wealth in the short straddle when holding for 30 days without being forced to liquidation before 2008 whereas they must have less than 1% (1/(107.55 + 1.54)) in the short 10% strangle during the same period to avoid liquidation.

The best performer with the inclusion of the margin account effect is the short gut which has fewer margin calls with lower average for all holding periods in both sample periods than other strategies. Its average margin call is lower than $0.20 for every dollar invested in the position and is associated with a much lower standard deviation across all time frames of trading. Even in the worst case, which is the 45-day maturity in the years after 2008, the margin haircut ratio is $2.64 with a margin call of 0.93 for every dollar invested as shown from both Tables 8 and 9. This leads to no margins being called if investors invest less than 28% of their wealth in the position. In this case, the short gut can be regarded as a very attractive position to investors who play on volatility trading as it allows more funds available to be in the position and still avoids forced liquidation.

Overall, margin account greatly affects the profitability of volatility trading as investors have to set aside a large proportion of their wealth into the margin account and also faces the risk of large margin calls. This particularly applies to the strategies that are cheap to construct. In contrast, the short straddle and particularly the short gut are more attractive as investors can afford to invest more aggressively while having less chance to liquidate the positions.

4. Conclusion

Earlier studies report unusually high profits for strategies that involve writing put options. The findings encounter great challenges by two recent papers, Santa-Clara and Saretto (2009) and Do et al. (2016), who show that the profitability of these trades may be significantly affected by the inclusion of trading frictions, such as bid-ask spreads and margin requirements.

This paper re-examines the trading profits of option volatility strategies in time-varying market conditions, with a particular focus on evaluating the authenticity of risk-adjusted returns. Specifically, we investigate the performance of 18 volatility strategies with the SPX options, including both long and short straddles, strangles, guts, strips and straps as well as more complex butterflies in both the pre-crisis and after-crisis periods from 2002 to 2007 and from 2008 to 2013, respectively.

Our baseline analysis shows that short volatility strategies usually generate higher profits than the benchmarks of an investment in the market index all the time and a short 10% OTM put. The short 10% strangle, for example, beat both benchmarks in almost all scenarios. On several occasions, however, the authenticity of such large profits does not stand up to scrutiny.

SPX options are subject to non-trivial trading frictions in the form of bid-ask spreads. When the option positions in use are assumed to be entered at the actual bid (ask) quotes, the economic value of volatility trading is greatly reduced though not eliminated. Furthermore, we also demonstrate that profits to short volatility strategies are significantly overstated when they are estimated without accounting for margin requirements. For strategies that are profitable, such as the short 10% strangle, it is very difficult to execute positions as investors are only able to invest a very small percentage of their wealth in the positions. In addition, when short positions move against investors, they must have adequate funds to cover the margin calls.

Overall, from a practical perspective, the modest volatility trading profits that survive real-world settings appear to hinge on the capability of investors to capture the volatility risk premium and to wisely time its trades. The suggestion therefore is to attach close attention to market volatility, the VIX index for example (Gonzalez-Perez, 2015), and construct trading strategies also on the basis of investors' wealth: for investors with adequate (limited) funds, having short strangles (gut) positions sold before maturity when there are no extreme shocks in the market tends to be an attractive option.

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References

Bakshi, G., & Kapadia, N. (2003). Delta-hedged gains and the negative market volatility risk premium. *Review of Financial Studies, 16*, 527–566.
Bates, D. S. (1996). Jumps and stochastic volatility: Exchange rate processes implicit in Deutsche mark options. *Review of Financial Studies, 9*, 69–107.
Bates, D. S. (2003). Empirical option pricing: A retrospective. *Journal of Econometrics, 116*, 387–404.
Black, F., & Scholes, M. (1973). The pricing of options and corporate liabilities. *Journal of Political Economy, 81*, 637–654.
Bondarenko, O. (2014). Why are put options so expensive? *Quarterly Journal of Finance, 4*, 1–50.
Broadie, M., Chernov, M., & Johannes, M. (2009). Understanding index option returns. *The Review of Financial Studies, 22*, 4493–4529.
Cao, C., & Huang, J. Z. (2007). Determinants of S&P 500 index option returns. *Review of Derivatives Research, 10*, 1–38.
Carverhill, A., Cheuk, T. H., & Dyrting, S. (2009). The smirk in the S&P 500 futures options prices: A linearized factor analysis. *Review of Derivatives Research, 12*, 109–139.
Chaput, J. S., & Edrington, L. H. (2005). Volatility trade design. *Journal of Futures Markets, 25*, 243–279.
Constantinides, G. M., Jackwerth, J. C., & Savov, A. (2013). The puzzle of index option returns. *Review of Asset Pricing Studies, 3*, 229–257.
Coval, J. D., & Shumway, T. (2001). Expected option returns. *Journal of Finance, 56*, 983–1009.
Do, B. H., Foster, A., & Gary, P. (2016). The profitability of volatility spread trading on ASX equity options. *The Journal of Futures Markets, 36*, 107–126.
Doran, J., & Fodor, A. (2008). *Is there money to be made investing in options? A historical perspective*. Working Paper. Florida: Florida State University.
Driessen, J., & Maenhout, P. (2007). An empirical portfolio perspective on option pricing anomalies. *Review of Finance, 11*, 561–603.
Driessen, J., & Maenhout, P. (2013). The world price of jump and volatility risk. *Journal of Banking & Finance, 37*, 518–536.
Driessen, J., Maenhout, P., & Vilkov, G. (2009). The price of correlation risk: Evidence from equity options. *Journal of Finance, 64*, 1377–1406.

Duarte, J., & Jones, C. S. (2007). *The price of market volatility risk*. Working Paper. Stanford University.
Duffie, D., Pan, J., & Singleton, K. (2000). Transform analysis and asset pricing for affine jump diffusions. *Econometrica, 68*, 1343–1376.
Fung, J. K. W. (2005). The information content of option implied volatility surrounding the 1997 Hong Kong stock market crash. *Journal of Futures Markets, 27*, 555–574.
Gonzalez-Perez, M. T. (2015). Model-free volatility indexes in the financial literature: A review. *International Review of Economics and Finance, 40*, 141–159.
Goyal, A., & Saretto, A. (2009). Cross-section of option returns and volatility. *Journal of Financial Economics, 94*, 310–326.
Heston, S. (1993). A closed-form solution of options with stochastic volatility with applications to bond and currency options. *Review of Financial Studies, 6*, 327–343.
Hull, J. (2009). *Options, futures, and other derivative securities* (5th ed.). Englewood Cliffs, NJ: Prentice-Hall.
Hull, J., & White, A. (1987). The price of options on assets with stochastic volatilities. *Journal of Finance, 42*, 281–300.
Jones, C. S. (2006). .A nonlinear factor analysis of S&P 500 index options returns. *Journal of Finance, 61*, 2325–2363.
Lin, Y. N., & Lin, A. Y. (2016). Using VIX futures to hedge forward implied volatility risk. *International Review of Economics and Finance, 43*, 88–106.
Liu, X. P. (2007). Returns to trading portfolios of FTSE 100 index options. *Applied Financial Economics, 17*, 1211–1225.
McDonald, R. L. (2012). *Derivatives markets* (3rd ed.). Boston: Pearson Addison Wesley.
Memmel, C. (2003). Performance hypothesis testing with the Sharpe ratio. *Finance Letters, 1*, 21–23.
Orosi, G. (2012). Empirical performance of a spline-based implied volatility surface. *Journal of Derivatives & Hedge Funds, 18*, 361–376.
Rubinstein, M. (1994). Implied binomial trees. *The Journal of Finance, 49*, 771–818.
Santa-Clara, P., & Saretto, A. (2009). Option strategies: Good deals and margin calls. *Journal of Financial Markets, 12*, 391–471.
Tzang, S. W., Wang, C. W., & Yu, M. T. (2016). Systematic risk and volatility skew. *International Review of Economics and Finance, 43*, 72–87.