Option Sellers Could Capture Time Decay with Short-Dated Index Options (Maybe Even During the Covid-19 Market Crash of 2020)

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Abstract

At-the-money short-dated call and put options have the highest speed of time decay. Writing straddles using these options initiates a delta neutral position. Straddles, however, offer a lower empirical buffer against changes in the underlying price. Forming a strangle by using paired out-of-the-money call and put options captures time decay and provides a buffer against underlying price changes. This strategy is delta-neutral at initiation and the delta can still be zero at expiration. We analyze the performance of straddles and strangles from 2010 to 2019 using daily S&P 500 Index option data. We incorporate exchange-mandated margins and bid-ask spreads. The positive average return for the short strangle strategy, about 3% per month, exceeded the average return for the riskier short straddle strategy. Risk-adjusted measures strongly favor the short strangle strategy. We then test whether these results are robust during 2020—a period that included the Covid-19 Crash and recovery. They are not. All average returns are negative. Option writers using a novel cash-recovery hedge, however, could profit.

JEL Classifications: G11, G13, G19

Keywords: Time decay, Option writing strategies, Short-dated index options, Strangle, Straddle

Option Sellers Could Capture Time Decay with Short-Dated Index Options (Maybe Even During the Covid-19 Market Crash of 2020)

Practitioners and academics alike have long known that option prices decay over time, all else equal. Professional traders say that capturing option time premium is a "real thing." Intrigued by this declaration, we search for and find conditions under which option writers can maximize risk-adjusted returns. These conditions involve writing short-dated option portfolios that minimize the effect of price changes in the underlying asset.

Although our empirical results do not require the Black and Scholes (1973) assumptions, a familiar way to think about the speed of time decay is by using theta, Θ, the partial derivative of the Black and Scholes (1973) option pricing model with respect to time. Although time is deterministic, theta is not constant. Theta varies by the level of volatility, option moneyness, and becomes more nonlinear as options approach expiration.

For any moneyness level, at-the-money call and put options have the highest Black and Scholes (1973) thetas. These thetas increase at an increasing rate and peak at expiration. Theoretically, then, simultaneously selling at-the-money call and put options with the same strike price and expiration date captures the highest time decay. By doing so, traders form a strategy called a straddle. At-the-money straddles are instantaneously delta neutral, so returns to this portfolio should approximate the risk-free rate. Yet Coval and Shumway (2001), in their seminal paper about this strategy, find that holders of delta-neutral straddle positions lose about three percent per week and conclude that option sellers should profit.

We argue, however, that simply using the negative of the dollar losses from a long straddle is appropriate to measure the dollar profits from a short straddle—but not the percentage returns. Short option positions require margin and this margin affects returns, as detailed by Choy and Wei (2022). Traders holding other financial assets can pledge some percent of these assets as margin. But we compute percentage returns using cash margin so the returns we report are a lower-bound.

Empirically, at initiation, the delta of an at-the-money short straddle strategy is near-zero. At expiration, however, the delta of this strategy is positive or negative one, almost surely. Despite having a near-zero delta at initiation, we find that the short straddle strategy provides a small buffer against subsequent changes in the underlying price. Although the short at-the-money straddle is designed to capture the most theta, it has a high exposure to changes in delta, i.e., a high gamma, which erodes profits.

We find that traders can still capture time decay, and be protected from changes in the underlying price if they use a less well-known strategy—a short strangle strategy. The strangle on which we focus is one in which traders sell a 5% out-of-the-money call and a 5% out-of-the-money put with the same expiration date.[1]

The 5% out-of-the-money short strangle strategy has a lower speed of time decay but a relatively low gamma exposure. Empirically, strangles also have a near-zero delta at initiation. At expiration, however, this strategy will have a delta of positive or negative one *or zero*—so the short strangle strategy provides a bigger buffer against changes in the underlying price. In fact, we find that the 5% strangle has a delta of zero at expiration in 463 of 473 weeks, or 97.9% of the time. Thus, we conjecture that trading off the higher theta of a straddle for the lower gamma of the strangle produces a higher risk-adjusted return.

Our primary data set is a comprehensive sample of S&P 500 option data from 2010 through 2019, which was provided by an anonymous firm through a Non-Disclosure Agreement. Subsequently, the anonymous firm sent us data from January 2020 through February 2021. This extended time period is a particularly harsh one in which to test the performance of short option strategies because of the major stock market crash and rapid recovery. Thus, we have data before and after the "Covid-19 Crash."

In addition to the short straddle and short strangle strategies, we also examine the short guts strategy, where traders write a 5% in-the-money call and put. We also examine two other strategies designed to improve the performance of the at-the-money short straddle. The first is what Coval and Shumway (2001) call the "crash-neutral" short straddle: traders

[1] Besides 5%, we also test 3% and 7% OTM options for rubustenss.

add a long position in a 10% out-of-the-money put. The second strategy, known as a long iron butterfly, adds a long position in a 10% OTM call to the "crash-neutral" short straddle.

We focus on S&P 500 options and use two trading schemes. Holding the strategies from the first Friday of a month to the first Friday of the following month is the "monthly scheme." In the monthly scheme, the strike prices do not change over the month. We call the other trading scheme the "weekly scheme." In the weekly scheme, we repeatedly initiate the strategy at the close of Friday and hold it to the close of the following Friday. Strike prices can change each week in the weekly scheme. We create synthetic monthly returns using four (or five) weekly returns so that results can be compared between the two schemes.

We measure monthly returns by incorporating the CBOE-mandated margin requirements for writing options. Using the bid-ask spread and the monthly trading scheme, both the at-the-money short straddle and the 5% out-of-the-money short strangle had positive monthly returns, 1.89% and 3.40%, respectively. The standard deviations were 9.78% and 8.63%. Using the bid-ask spread and the weekly trading scheme, synthetic monthly returns for both strategies fell—to 0.17% and 2.30%, respectively. The standard deviation for the short straddle increased to 14.69%, however, it nearly fell in half for the short strangle—to 4.54%.

We use four well-known risk-adjusted performance measures for the five strategies. The 5% out-of-the-money short straddle in both trading schemes consistently outperformed the other four strategies whether we use the Sharpe ratio, the Sortino ratio, Leland's alpha, or the Manipulation-Proof Performance Measure (using three levels of risk aversion).

We also perform tests using a "Covid-19 Crash" sample from January 2020 through February 2021. This time period is a particularly harsh one in which to test the performance of short option strategies because of the major stock market crash and rapid recovery between February 2020 and April 2020, i.e., the Covid-19 Crash. The short straddle had negative returns, as did the "crash-neutral" short straddle and the long iron butterfly. The returns from these last two strategies were not as negative as the short straddle, but, perhaps surprisingly, were more negative than the returns from the short strangle.

Throughout the Covid-19 sample period, we employ a robotic trading strategy in which we assume that traders looked to alter their portfolios daily, at the close. We introduce the "Dollar Loss Recovery" hedge, which does not restore delta neutrality. First, the trader calculates the intrinsic value of the position and subtracts it from the option premium received at initiation. If the difference is positive, the trader does nothing. If the difference is negative, the trader infuses enough cash by selling at-the-money options to establish a break-even position at the end of the day. For example, if the underlying has fallen to a level where the short put leg has a loss, the trader recovers the loss by selling call options.

Employing this strategy, we find the cumulative dollar profit of $1,000 initial investment grew from $10,868 at the end of December 2019 to $30,051 at the end of February 2021, 8.45 times higher than the cumulative profits of the unhedged weekly short strangle strategy. In part, this return stemmed from the sale of options with high premiums, which reflected the high option-implied volatility during that time.

In sum, we add to the existing literature on the performance of option writing strategies by providing a theoretically-based empirical study of how best to capture the nonlinear nature of the decay in option time value while accounting for the bid-ask spread and the effects of margin. In addition, we decompose the returns to the strangle, and document that the returns to the legs are consistent with economic predictions. Short put leg returns are generally positive: shorting puts provides valuable insurance. Short call leg returns are generally negative: adding a short call leg makes the strangle delta neutral, but at the cost of buying gamma risk insurance.

The paper proceeds as follows. We begin by describing our motivation and the strategies. Then we describe the data and trading schemes. We then present our major empirical results by trading scheme for the five portfolios that we study. We examine the performance of the strategies over a sample that includes the Covid-19 Crash of 2020. The strategies generate negative returns over this 14-month sample—but the bulk of the losses are in five weeks. We close by showing how users of a novel cash-recovery hedge could preserve trading capital.

1. The Motivation for Strategies Used and a Short Literature Summary

1.1 The Motivation for Strategies Used

Traders told us that they seek to capture the decay in option premiums. But how do they do it? We set out to test a set of option writing strategies using mechanical trading systems. Our starting point is to find a strategy designed to capture the most option time decay.

Using the Black-Scholes model as a reference, given a volatility level, short-dated at-the-money options have the highest speed of time decay across all levels of moneyness. Theoretically, then, simultaneously writing short-dated, at-the-money call and put options with the same expiration date should be the optimal option strategy to capture time decay. This strategy is known as a short straddle.[2]

Panel A of Figure 1 shows the short straddle payoff at expiration. While the option is still alive, the payoff from the strategy grows into the triangle as time to expiration falls, all else equal. Thus, the profit of a short straddle strategy is capped by the combined option premiums received by the option writer. The maximum profit is realized if the price of the underlying security equals the strike price at expiration. The downside risk of the short straddle, however, is uncapped. Any deviation of the underlying stock prices from the strike price will erode profits and could result in substantial losses. For example, in Panel A of Figure 1, if the underlying price subsequently moves less than 5%, traders will profit. If the price moves more than 5% in either direction, traders incur losses.

Traders could sacrifice the relatively high speed of time decay for less risk introduced by changes in the underlying asset price. Compared to at-the-money options, out-of-the-money options have relatively lower thetas, but they also have less gamma exposure. Like a short straddle, traders write call and put options with the same level of moneyness to achieve a delta-neutral portfolio. Traders construct a short strangle by simultaneously writing an

[2]Note, however, that once the underlying price deviates from the strike price for at-the-money options, the speed of time decay decreases. For example, 5 days before expiration, the theta of a short straddle strategy changes from \$0.7002 to \$0.6556, or -6.4%, if the underlying price drops 1%.

out-of-the-money call option and an out-of-the-money put option with the same level of moneyness and expiration date.

Figure 1 illustrates the short strangle payoff diagram in Panel B. The profit from a short strangle, like the profit from a short straddle, is capped by the combined option premium collected by the option writer. Traders holding a short strangle position, in contrast to a short straddle strategy, could still earn this maximum profit if the change in the underlying price is less than 5% (plus the amount of the premium collected, i.e., in the trapezoid). Although the downward risk of a short strangle is also uncapped, traders will not incur losses as shown in Figure 1, until the underlying asset price change exceeds 7.5% (in either direction), as compared to 5% for the short straddle.[3]

The short strangle strategy has less time value to collect. For example, in our example, the highest theta is $0.74 for a short strangle, while the highest theta for a short straddle is $1.57. Still, a short strangle strategy could produce better performance than a short straddle if the underlying price changes.

We also include the short guts strategy, which is a special variant of the short strangle strategy. The short guts strategy is constructed by simultaneously writing an in-the-money call option and an in-the-money put option with the same level of moneyness and expiration date. The short guts strategy has a similar payoff diagram and patterns of time decay as a short strangle that uses out-of-the-money options.

Although the short strangle strategy provides traders a buffer against changes in the underlying prices, traders should not neglect the lessons learned from market crashes. To protect themselves from market turmoil, traders could add an offsetting long position in a deep out-of-the-money put to their short straddle strategy as a safety net. Coval and Shumway (2001) call this strategy the "crash-neutral" straddle.

While the chance of an upward jump in the underlying price is likely much lower than the

[3] In the straddle and strangle figures, to compute the maximum payoff amount, we set the stock price to $300, the strike price of the at-the-money options is $300, the strike prices of the out-of-the-money call and put option are $315 and $285, respectively, the implied volatility is 25%, the risk-free rate is 1% and the time to expiration is 30 days.

chance of a sudden market crash, the chance is not zero. Traders could address this concern by adding a long position in a deep out-of-the-money call to the "crash-neutral" straddle. The resulting strategy is known as a Long Iron Butterfly.[4]

Investigating these strategies allows us to test (ex-post) whether the insurance provided to traders from these strategies helps the performance of a short straddle strategy. It might be that these insurance policies, in retrospect, do not provide worthwhile insurance. Because insurance premiums provide the holder with losses against unforeseen events, holding insurance could lead to lower returns. We list the components of each strategy in Table 1. Panel C of Figure 1 illustrates the payoff diagram of all these option writing strategies.[5]

1.2 Academic Research on Straddles and Strangles

Broadie, Chernov, and Johannes (2009) summarized, "strategies that involve writing options generally deliver higher average returns than [the] underlying asset..." Straddle strategies have been studied by academic researchers in a number of circumstances. Noh, Engle, and Kane (1994) test SPX option market efficiency by making daily estimates of the volatility and straddle prices for the next day. Their GARCH model method generates abnormally high positive returns.[6]

Coval and Shumway (2001) study the returns of a delta-neutral straddle using options on the S&P 500 Index (SPX) from January 1990 through October 1995. The long at-the-money SPX straddles have average returns of -3.15% per week, and straddles with strike prices away from at-the-money suffer even larger losses. Their results suggest that traders could earn

[4] In this paper, we use the Iron Butterfly (and the Iron Condor) strategies because they naturally build on previous strategies. That is, testing the performance of the Iron Butterfly strategy, for example, is a direct test of an insurance strategy for the short straddle strategy. The careful reader will notice that the traditional Butterfly strategy using all calls or all puts has a similar payoff pattern as the Iron Butterfly strategy, and is also delta-neutral.

[5] Note that the short guts strategy has a payoff diagram similar to the short strangle strategy.

[6] On each day, Noh et al. (1994) estimate the volatility and straddle prices for the next day using either a GARCH model or an implied volatility regression model. Engle and Rosenberg (2000) study the efficiency of different methods of hedging against changes in volatility by using straddles. Guo (2000) studies whether the volatility prediction is economically meaningful using foreign currency options. Similar to Noh et al. (1994), Guo (2000) uses a long or short straddle based on the model prices estimated by an ISVR or GARCH model. Guo (2000) results echo previous findings. Introducing transaction costs makes economic profits disappear.

about 3% per week on short straddles—-without exposing themselves to significant market risk. Coval and Shumway (2001), however, do not account for the margin cost of writing options. We show that one cannot simply assume that the option writers earn the reverse of the loss of the option buyers.[7]

Goltz and Lai (2009) extend the Coval and Shumway (2001) study by analyzing the return characteristics for at-the-money straddles using Deutscher Aktienindex (DAX) from January 1999 through December 2005. Goltz and Lai (2009) use daily, weekly, and monthly rebalancing frequencies when calculating the straddle returns. Goltz and Lai (2009) suggest that straddle returns do not lead to any realistic investment opportunities, because the transaction cost of a higher rebalancing frequency would swamp the gains from a short straddle strategy.

By contrast, there are few studies on strangle strategies, and none on European-style index options. Chaput and Ederington (2005) study several volatility trades using options data on American-style Eurodollar futures.[8] Santa-Clara and Saretto (2009) show that margins negatively impact the realized return of option trading strategies, including straddle and strangle strategies, using American options on S&P 500 futures contracts.

[7]Further, we show that this approach is problematic when options are held to expiration. Coval and Shumway (2001) also examine the returns of a crash-neutral straddle, which adds a deeply out-of-the-money long put option to the straddle. Over the main sample period, the crash-neutral straddle offers a Sharpe ratio of up to twice that of the underlying S&P 500 Index. The result is robust to adding transaction costs.

[8]Using a unique data set provided by Bear Brokerage, they identify the spread and combination trades from separate trades of calls and puts. They find straddles (62%) and strangles (18%) are mostly traded strategies among volatility trades. They find most (71%) straddles are at the closest-to-the-money strike to minimize the Black model delta while maximizing gamma and vega. Strangle traders, on the other hand, choose strike price pair whose geometric mean is close to the underlying futures. Moreover, traders tend to choose straddles when the underlying futures are close to a traded strike and a strangle otherwise. Finally, the level of implied volatility has little influence on volatility trade design.

2. Empirical Design

2.1 Data Description

The primary data set for this study consists of a comprehensive sample of option data provided by an anonymous firm through a nondisclosure agreement. The data consists of descriptive option information, option prices, bid/ask quotes 15-minute before the close, closing bid/ask quotes, option open interest, daily trading volume, implied volatility, and other option Greeks.

The initial data sent to us runs from December 2010 through December 2019. Subsequently, the firm sent us additional data that runs from January 2020 through February 2021. This extended sample period is atypical. There was a significant one-month market break at the onset of the Covid-19 pandemic. In addition, there was a rapid market rally following this break. This extended period presents a severe stress test to option strategies containing short positions.

As in Coval and Shumway (2001), we present results using the midpoint of the bid-ask spread. Guo (2000) and Goltz and Lai (2009), however, illustrate that using the full bid-ask spread could wipe out the outperformance of certain option writing strategies. Therefore, we also report results using the closing bid prices to initiate short positions for both the weekly and the monthly schemes. In addition, we use the closing ask prices to close the short positions each month for the monthly scheme.

2.2 Option Selection Details

The theoretical predictions regarding time decay are based on the Black-Scholes option pricing model. Thus, we pick an underlying asset that fits the model assumptions as closely as possible: the options must have European-style exercise, and should be on an underlying asset that does not pay dividends. We use European options on the S&P 500 Index. Although the index consists mainly of stocks that pay dividends, the effect of dividends is minimized for short-dated options.

We use the well-known SPX options with their third-Friday-of-the-month expirations in the "Monthly Trading Scheme." The options we use for the "Weekly Trading Scheme" are mostly the short-dated SPXW weekly options. These options expire Friday afternoon, except for the third Friday of every month. For that week, we use the SPX option with five days to expiration.[9]

The SPXW Weekly Options are a relatively new product. On December 02, 2010, the CBOE terminated the existing A.M.-settled S&P 500 Index "Weeklys" options and switched to the P.M.-settled S&P 500 Index options. These new P.M.-settled SPX Weekly options were listed to expire on any Friday of the month, other than the third Friday.[10]

Trading volume of weekly options has surged since that transition. Our sample starts on December 02, 2010, and only include the P.M.-settled S&P 500 Index "End-of-Week (EOWs)" options.[11]

Our dataset contains the option strike price, option type (call or put), option open interest and trading volume, implied volatility, and Greeks (delta, theta, vega, and gamma). We calculate the time to expiration as the difference between the expiration date and the

[9] After the pilot "Weeklys" program was approved by the SEC, the CBOE listed the first S&P 500 Index weekly option series on October 28, 2005. These options were A.M.-settled and listed to expire on any Friday of the month, other than the third Friday. On December 02, 2010, the CBOE terminated the A.M.-settled S&P 500 Index "Weeklys" program and switched to the P.M.-settled S&P 500 Index "End-of-Week (EOWs)" pilot program (after SEC approval). A more detailed chronicle with information collected from the SEC and the CBOE is available upon request.

[10] Besides every third Friday, the P.M.-settled SPX Weeklys will also not be listed on the Friday that coincides with an expiration date of the S&P 500 Index End-of-Month (EOMs) option or the S&P 500 Index Quarterly (SPXQ) option. Basically, if the last trading day of a month is a Friday, the P.M.-settled SPX Weeklys will not be listed for that week. In those cases, we will use the standard SPX, End-of-Month, or SPXQ options with corresponding expiration dates instead in the weekly trading scheme.

[11] On any specific trading day, the root symbols and expiration dates can be used to separate types of S&P 500 Index options. For example, after the CBOE adopted the Options Symbology Initiative system (OSI) in May 2010, the root of the standard monthly option on the S&P 500 Index is "SPX," while the root of the P.M.-settled S&P 500 End-of-Week option is "SPXW." On May 01, 2017, the CBOE moved the P.M.-settled S&P 500 Index monthly options to the Hybrid 3.0 S&P 500 Index options class and changed their root symbols to "SPXW," i.e., the same as the SPX weekly options. Nevertheless, to maintain consistency, we use the standard SPX options on the third week of each month in the weekly trading scheme. Before May 2010, the root symbols of A.M.-settled SPX Weeklys Options are JXA, JXB, JXD, JXE (Week 1, 2, 4, and 5 root symbols). Between May 2010 and December 2010 when it finally stopped trading, the A.M.-settled SPX Weeklys Options and the standard SPX Monthly Options shared the same "SPX" root symbol. The only way to distinguish them is by expiration dates.

quote date. Our option data set does not contain the index level at the end of the day. Thus, we collect the closing level of the S&P 500 Index and T-bill data from CRSP. Option moneyness is then determined by comparing the strike price of the option to the closing level of the S&P 500 Index.

For baseline results, we assume traders buy or sell options at the midpoint of the closing bid and ask prices, as suggested by Blume and Stambaugh (1983). To incorporate full transaction costs, we assume that options are purchased at the ask prices and sold at the bid prices. Because options in the weekly trading scheme will be held until expiration, we collect the settlement values of those options from the CBOE website to calculate the expiration payoff.[12]

At-the-money call and put options are chosen for the short straddle strategy; 5% out-of-the-money call and put options are chosen for the short strangle strategy;[13] 5% in-the-money call and put options are chosen for the short guts strategy; 10% out-of-the-money put and call options are chosen as downside and upside insurance for the "crash-neutral" short straddle strategy and the long iron butterfly strategy.[14]

2.3 Holding Period Details

In this study, we replace the options in the monthly trading scheme each month while we replace the options in the weekly trading scheme every Friday after the existing ones expire. Figure 2 illustrates the details of the rebalancing process for the monthly trading scheme and the weekly trading scheme. Specifically, on the first Friday of each month, traders construct the monthly trading scheme by writing standard SPX options that expire in the next month. They hold these options until the first Friday of the following month, close their

[12] `https://www.cboe.com/index_settlement_values/weeklys_settlement_values/`

[13] We also test the performance of the short strangle strategy with 3% and 7% out-of-the-money call and put options for robustness.

[14] If the underlying prices do not fall exactly on an available strike price, we choose the next available option that is slightly out-of-the-money (in-the-money) for the short strangle (guts), and slightly out-of-the-money call option and in-the-money put option combination is chosen for the short straddle. If 10% out-of-the-money call options are not listed on a given Friday, we choose the call option with the highest available strike price for the long iron butterfly.

current positions, and establish new short positions. We repeat this procedure each month.

Beginning on the first Friday of each month, we assume traders construct the weekly trading scheme by writing SPXW weekly call and put options that expire the following Friday. We assume traders hold the short positions until expiration.

We cannot directly compare the monthly returns from the monthly trading scheme with the weekly returns from the weekly trading scheme. To make the returns comparable, we combine the returns of the individual weeks from the weekly trading scheme that lie within the same month, and match them with the holding periods of the monthly trading scheme. For example, we use the weekly returns in August from the weekly trading scheme to calculate the corresponding monthly return, and then compare this return to the August monthly return from the monthly trading scheme.

We calculate the monthly dollar returns from the weekly trading scheme as

$$Dollar_j^{M(onthly)} = \sum_{i=1}^{4} Dollar\ returns_{i,j}{}^{weekly} \tag{1}$$

The monthly percentage return from the weekly trading scheme is

$$R_j^{M(onthly)} = \prod_{i=1}^{4} (1 + R_{\text{short } i,j}^{weekly}) - 1 \tag{2}$$

where terms on the right-hand side of the equations are the weekly dollar and percentage returns of the weekly trading scheme in Week i of Month j.[15]

3. The Monthly Trading Scheme Versus The Weekly Trading Scheme

The sample period begins on December 3, 2010. This date is when the P.M.-settled SPX End-of-Week Option Series began trading. The sample period ends on December 27, 2019. There are 109 monthly observations for the monthly trading scheme and 473 observations

[15]Note that in most cases, there are four weeks in a given month. However, in some cases, there are months that have five weeks.

for the weekly trading scheme.

3.1 Comparing the Dollar Returns from the Five Strategies

Table 2 contains summary statistics of the monthly dollar returns for the at-the-money (ATM) short straddle, the "crash-neutral" short straddle, the 10% long iron butterfly, the 3%, 5%, and 7% out-of-the-money (OTM) short strangle, and the 5% in-the-money (ITM) short guts strategies. The dollar returns presented are for the terminal payoff of the strategies. In each panel, the results in the top sub-panel are for the monthly trading scheme, while the ones on the bottom sub-panel are for the weekly trading scheme. Although initiation of each of these short positions by individual traders has an actual margin requirement, this direct cost, nor the opportunity cost, are included in the calculation of dollar returns.

Panel A of Table 2 contains the monthly dollar returns for each strategy using the mid-points of the bid-ask spread. From the monthly trading scheme, the short straddle strategy has the second-highest average monthly return and the highest standard deviation \$8.72 and \$27.51, respectively. Note that the results reported in Table 2 are per share basis. Traders have to write at least one contract, which contains 100 shares, in practice. That is, the short straddle average monthly dollar return and standard deviation per contract are \$872 and \$2,751, respectively. As expected, the "crash-neutral" short straddle strategy and the long iron butterfly strategy do have a lower standard deviation (\$24.70 and \$24.48) compared to the short straddle strategy. On average the insurance feature, however, erodes half of the dollar returns (\$4.48 and \$4.19) of the (uninsured) short straddle strategy. Even with their insurance features, however, these two straddle-related strategies still have higher standard deviations than the short strangle and the short guts strategies.

The 3% OTM short strangle strategy has the highest average monthly dollar return (\$8.80) and the highest standard deviation (\$20.51) among the three moneyness levels we test for the short strangle strategy. As the moneyness moves further out of the money, both the average monthly dollar return and the standard deviation decrease. The 5% and

7% OTM short strangle strategy have an average monthly return of \$8.09 and \$6.50, and standard deviations of \$14.51 and \$9.72, respectively. The 5% ITM short guts strategy has a similar average monthly return (\$7.91) and standard deviation (\$14.51) as the 5% OTM short strangle strategy.

Panel B of Table 2 contains the dollar returns of the five option writing strategies using the bid and ask prices. Using bid and ask prices negatively impacts the average returns of all strategies. From the monthly trading scheme, the short strangle strategy now dominates the other four strategies with the highest average dollar returns and lowest standard deviations. The 3%, 5%, and 7% OTM short strangle strategy have average monthly return of \$6.64, \$6.52, and \$5.17, and standard deviations of \$20.75, \$14.67, and \$9.86, respectively.

The short straddle strategy has the next highest average monthly return but the highest standard deviation, \$5.10 and \$27.58, respectively. The transaction costs have a dramatic impact on the other strategies. For example, the transaction costs almost wipe out all the dollar returns of the short guts strategy (from \$7.91 to \$0.77).[16] The monthly average dollar returns of the "crash-neutral" short straddle strategy and the long iron butterfly strategy drop to \$1.55 and \$1.54, respectively.

The bottom panels of Table 2 contain the dollar returns of the five option writing strategies from the weekly trading scheme. In general, the average monthly returns from the weekly trading scheme are lower, or even negative, compared with the same strategy in the monthly trading scheme.

The out-of-the-money short strangle strategy has the highest average monthly returns and the lowest standard deviations. From Panel A, using bid-ask midpoints, the 3%, 5%, and 7% OTM short strangle strategy have average monthly returns of \$6.63, \$5.23, and \$3.43, and standard deviations of \$15.74, \$6.90, and \$4.11, respectively. From Panel B, using the full bid-ask spread, the 3%, 5%, and 7% OTM short strangle strategy have average monthly

[16]This is not a surprising result. The short guts strategy uses in-the-money options, which are relatively more expensive than the out-of-the-money options used in the short strangle strategy. These expensive in-the-money options by nature have a wider bid-ask spread, i.e., higher transaction costs.

returns of \$5.03, \$4.21, and \$2.66, and standard deviations of \$15.53, \$6.21, and \$3.51, respectively. Similar to the monthly trading scheme, as the moneyness moves further out of the money, both the average monthly dollar return and the standard deviation decrease.

The other four strategies generated losses, on average, when using bids versus midpoints of the bid-ask spread. Surprisingly, the short straddle strategy does not perform as well as expected in the short-dated environment. The average monthly return of the short straddle strategy is \$3.90 using bid-ask midpoints (from Panel A), and -\$1.12 using bids (from Panel B). The standard deviation is \$48.41 and \$49.02, respectively.

Overall, the results for the dollar returns provide an overview of the payoff for each option writing strategy. Theoretically, if a trader had an unlimited source of funds, the trader could write an unlimited number of options—and perhaps dollar returns matter most to these traders. In reality, however, traders make decisions based on percentage returns. We now shift our focus to the percentage returns from each strategy.

3.2 Comparing the Percentage Returns from the Five Option Writing Strategies

3.2.1 A Note on the Zero-sum Approach to Calculate Short Option Returns

A common method used in previous papers (Coval & Shumway, 2001; Goltz & Lai, 2009; Jha & Kalimipalli, 2010) is a zero-sum approach. In this approach, the researcher simply assigns a negative value to the percentage returns of a long position. By using the zero-sum approach, previous researchers implicitly assume the initial cost of a short position is also equal to the option premium. When shorting options, however, there is an additional cost—traders must post margin. For traders with an unlimited source of funds, dollar returns are all that matters and posting margin is not an issue—unless traders want to compare strategies on a risk-adjusted basis. In Appendix C.1, we provide a more detailed discussion about the zero-sum approach and the approach we use, namely the net margin approach.

3.2.2 Short Option Percentage Returns using the Net Margin Approach

Table 3 presents summary statistics for the monthly percentage returns generated by the net margin approach for the five option writing strategies. Panel A presents returns from both the monthly trading scheme and the weekly trading scheme using the midpoints of the bid-ask spread and Panel B contains the results from the weekly trading scheme.

From the monthly trading scheme in Panel A1, the out-of-the-money short strangle strategy produces the highest average monthly percentage returns. The 3%, 5%, and 7% OTM short strangle strategy have average monthly return of 3.97%, 4.35%, and 3.53% (or approximately 42-52% annually), and standard deviations of 9.76%, 8.69%, and 6.27%, respectively. The 5% OTM short strangle produces the highest monthly return, while the 7% OTM short strangle has the second-lowest standard deviation.

The short straddle strategy has a lower average monthly percentage return, 3.22%, and a higher standard deviation, 9.85%. The "crash-neutral" short straddle strategy and long iron butterfly strategy provide the lowest average monthly percentage returns (1.66% and 1.55%, respectively), but lower standard deviations (8.26% and 8.11%), compared with the un-insured short straddle strategy.

From Panel B1 of Table 3, using the full bid-ask spread and the monthly trading scheme, the 5% OTM short strangle and the ATM short straddle strategies generated, on average, monthly percentage returns of 3.40% and 1.89%, respectively.

Panels A2 and B2 of Table 3 contain the percentage returns of the five option writing strategies from the weekly trading scheme. Similar to the previous results in Table 2, strategies with the weekly trading scheme generally produce lower, or even negative, returns using the full bid-ask spread. Using the weekly trading scheme, the short strangle strategies produces slightly lower average monthly returns and much lower standard deviations compared to the monthly trading scheme. From Panel A2, using bid-ask midpoints, the 3%, 5%, and 7% OTM short strangle strategy have average monthly return of 3.21%, 2.96%, and 2.00%, and standard deviations of 7.71%, 5.44%, and 3.34%, respectively. From Panel B2, using the full bid-ask spread, the 3%, 5%, and 7% OTM short strangle strategy have average monthly return of 2.38%, 2.30%, and 1.53%, and standard deviations of 7.25%, 4.54%, and 2.75%, respectively.

As shown in Panels A2 and B2, the short straddle strategy generated lower returns (2.08% and 0.17%, respectively) than most short strangles, but had much higher standard deviations (15.02% and 14.69%, respectively) compared to any short strangle. The "crash-neutral" short straddle strategy and the long iron butterfly strategy have lower standard deviations compared to the short straddle strategy. Even with their insurance features, however, these two straddle-related strategies still have higher standard deviations than any short strangle strategy. Moreover, using the full bid-ask spread, the "crash-neutral" short straddle strategy and the long iron butterfly strategy produce losses on average (-0.59% and -0.69%, respectively).

3.3 Judging the Risk-Adjusted Performance of the Five Option Writing Strategies

Despite their possible shortcomings, CAPM-based performance measures are still widely used in academia and the option trading industry. Their advantages, such as being easy to understand and easy to calculate, make CAPM-based measures quite suitable in situations where the trader must make a quick decision with limited time or information. As such, we calculate the Sharpe ratio and the Sortino ratio for each option writing strategy from both the monthly and the weekly trading schemes.

In regard to the normality of returns, Table 3 displays that the returns on all option writing strategies from any trading scheme exhibit negative skewness and positive excess kurtosis. In other words, assuming the normality of returns is problematic. As a result, besides the two well-known CAPM-based risk-adjusted performance measures, we also include results produced by Leland's Alpha and manipulation-proof performance measures (MPPM) from Ingersoll et al. (2007). Those measures can provide more accurate performance results if the CAPM-based measures are distorted by the return distribution in the sample.

Table 4 provides the performance measure results using the midpoints of the bid-ask spread in Panel A, and using the full bid-ask spread in Panel B. From Panel A, the 7% OTM short strangle strategy from the weekly trading scheme produces the highest Sharpe ratio and Sotino ratio compared to all other strategies from the either trading scheme. The 5% OTM short strangle strategy from the weekly trading scheme produces the highest Leland's Alpha and MPPM with high risk aversion (i.e., coefficient $\rho = 4$). The 5% OTM short strangle strategy from the monthly trading scheme produces the highest MPPM with low risk aversion (i.e., coefficient $\rho = 2$).

The short straddle strategy from either the monthly or the weekly trading scheme produces lower performance than the short strangle strategies. The strategies with insurance, i.e., the crash-neutral short straddle and long iron butterfly strategies, underperform the short straddle strategy from the corresponding trading scheme. The 5% ITM short guts strategy produces slightly lower performances than the 5% OTM short strangle strategy.

From Panel B, after using bid and ask prices, the short strangle strategy from the weekly trading scheme further outperforms, except in MPPM with low risk aversion coefficient $\rho = 2$. The 7% OTM short strangle strategy from the weekly trading scheme produces the highest Sharpe ratio and Sotino ratio, while the 5% OTM short strangle strategy from the weekly trading scheme produces the highest Leland's Alpha and MPPM with medium to high risk aversion (i.e., coefficient $\rho = 3$ or 4). The 5% OTM short strangle strategy from the monthly trading scheme still produces the highest MPPM with low risk aversion (i.e., coefficient $\rho = 2$).

The risk-adjusted performance of the short straddle strategy from the monthly trading scheme becomes either negative or barely above zero after introducing transaction costs. The weekly short straddle strategy performs poorly—it even producing negative Leland's Alpha and MPPM measures no matter which coefficients we use.

Recall the main purpose of this paper is to explore conditions under which traders can maximize the return while minimizing the risk of the option writing strategy. Clearly, the short strangle strategy accomplishes this goal in this sample and with the current research design. The short straddle strategy from the weekly trading scheme, which has the highest theoretical time decay and is thus expected to perform the best, surprisingly did not perform well in our sample. Specifically, after introducing transaction costs, the risk-adjusted performances of the short straddle strategy are either negative or barely above zero.

3.4 Robustness: Weekly Trading Scheme Starting from Other Weeks to Expiration

Theoretically, an out-of-the-money option produces the highest Black-Scholes theta in the middle of its life. So constructing the short strangle strategy with options that are only one week from expiration might not have the highest profit. Consequently, we explore some alternative trading schemes that hold the option position for one week–but starting at different weeks to maturity. For example, in the first alternative design, we construct the weekly trading scheme by writing weekly options on a Friday that they are two weeks from expiration. We hold the short positions until next Friday, close the current positions, and establish new short positions with options that are two weeks from expiration. We repeat this procedure each week. We test options two to six weeks from expiration.

Table 5 contains the summary statistics for weekly percentage returns of the short straddle and short strangle strategies. We compare the five alternative weekly trading schemes (2 Weeks - 6 Weeks) with the original design (1 Week), using bid-ask midpoints as well as bids and asks. Note instead of 473 weeks of observations, we only have a subsample of 311 weeks in this table. This is because CBOE did not introduce the longer expiration weekly options when they initially pilot the new P.M.-settled SPX Weekly options. So we match the subsample with the newest available product, the 6 Weeks to expire weekly options.

From Table 5, for both the short straddle and the short strangle strategies, those alternative weekly trading scheme designs do not improve the strategy returns. For example, from Panel B, as the weeks to expiration increase, the average weekly returns decrease while the standard deviations increase.

4. Investigating the Results from December 2010 through December 2019

4.1 Portfolio Mean Returns and Standard Deviations by Strategy

Figure 3 is a plot of the average monthly return and standard deviation, from December 2010 through December 2019. This figure contains the average monthly return and standard deviation for the S&P 500 and for two different rebalancing schemes: Monthly–denoted with an "M" and weekly–denoted with a "W." For each scheme, there are four option writing strategies: an at-the-money straddle, (ATM_Straddle), 3% out-of-the-money strangle, (3OTM_Strangle), 5% out-of-the-money strangle, (5OTM_Strangle), and 7% out-of-the-money strangle, (7OTM_Strangle).

The 7% out-of-the-money strangle strategy, rebalancing weekly has more return and less risk than the S&P 500. The 5% out-of-the-money strangle strategy, rebalancing weekly, has more return and more risk compared to the 7% out-of-the-money strangle strategy. The 3% out-of-the-money strangle has about the same risk-reward ratio as the S&P 500. The risk-reward ratio of the S&P 500 dominates the monthly or weekly at-the-money straddle, iron butterfly, the crash-neutral strategy, and the 5% in-the-money guts strategy. Overall, we see that the risk-reward ratios of the set of strangle strategies dominates the risk-reward ratios of the other strategies.

4.2 The Greeks at Initiation and Expiration

4.2.1 Theoretical Underpinnings

Firms purchase a variety of insurance contracts to insure the value of their real assets from adverse states of the world, e.g., fire, theft, wind damage, and floods. In financial markets, put option buyers pay a fee to option writers who are, effectively, providing wealth insurance against adverse price movements. The price of this insurance protection, however, is not constant. It is well-known that option premiums decay over time, all else equal.

Asset pricing theory predicts that risky securities, including put options, must compensate their holders with expected systematic risk-adjusted returns. Because put option writers face the risk of a future state of the world where the option contract is valuable, the returns from put option positions should flow to the sellers and buyers, on average, should expect to lose money on these contracts.

Like any insurance contract, the buyer of an option must pay the seller to take the risk of a future state of the world where the option contract is valuable. This insurance feature can best be seen by adding a long put position to a long stock position, i.e., "crash insurance." If the stock price plummets, the put option becomes valuable. If the stock price remains stable until the contract expires, the holder of the crash insurance suffers a loss in the option contract position.

The option insurance feature can be easily seen by adding a long put position to a long stock position. If the stock price plummets, the put option becomes valuable–it provides "crash insurance." If the stock price remains stable until the contract expires, the holder of the crash insurance suffers a loss in the option contract position.

The holder of a long stock position can also sell off potential gains in their long stock position by selling a call option to someone who thinks the stock price will increase before the option expires. If the stock price remains stable until the contract expires, the proceeds from selling the call option provide income when the stock price does not change.

In a strangle portfolio, traders can add a short call position to mitigate the effects of the movement of the underlying asset. That is, adding a short call position should result in a delta that is near zero. We note, however, that the benefit of adding the short call to form a delta-neutral strategy likely comes at a cost. That is, the profits from this short leg could be less than zero. We investigate the profits by legs in a later section.

4.2.2 A Deeper Look at the Empirical Results for the Weekly Trading Scheme

Table 6 presents the Greeks at initiation for the weekly rebalancing short straddle and three short strangle strategies. We see that all strategies are nearly delta-neutral at initiation.

We have shown that there is a trade-off between the speed of collecting options' time value (theta) and risk exposures from big jumps in underlying prices (gamma). In our sample, the short straddle has the highest theta and gamma on average, 1.99 and -0.0262, respectively. As option moneyness moves further away into out-of-the-money, both theta and gamma decrease. Specifically, the theta fell 57.1%, 74.7%, and 83.0%, on average, for the 3%, 5%, and 7% out-of-the-money short strangle strategies, as compared with the short straddle strategy. The gamma exposures, on the other hand, decreased by 78.8%, 92.0%, and 96.3%, compared to the short straddle strategy. This result echoes the previous ones that the short strangle strategy, in general, produces better risk-adjusted performance over the short straddle strategy.

As for the individual legs of the strategies, the short at-the-money call and put legs from the short straddle have the highest speed of time decay at initiation, as predicted by theory. The short call leg has a slightly higher theta on average than the short put leg. The short strangle strategies, on the other hand, show different patterns. At initiation, the out-of-the-money short put legs have higher theta on average than the short call legs. The higher the moneyness is, the more pronounced the difference between short call and put legs.

At expiration, the at-the-money short straddle is not delta-neutral. It had a delta of one 267 times, which means the S&P 500 index level was less than the put (and call) strike price in these cases. By way of contrast, the 5% out-of-the-money strangle was still delta neutral at expiration 463 times out of 473 weeks, or in 97.9% of the sample from 2010 to 2019.

In terms of dollar profits, consistent with the theoretical conjecture, we show that the put leg generates a profit for the straddle and the three strangles. This result holds whether the bid-ask midpoint is used as a reference for the option premium received or if the bid price is used. The call leg loses, on average, in the straddle strategy, and this loss is deep enough to make the dollar return for the short straddle smaller than for any of the three strangles. The short call leg for strangles had a small loss or small gain, on average.

4.2.3 A Deeper Look at the Empirical Results for the Monthly Trading Scheme

Table 7 displays the dollar profits or losses for the monthly rebalancing short straddle and three short strangle strategies. Using bid prices at initiation and ask prices when the position rolls over, all three short strangle strategies produce higher average dollar returns and lower standard deviations. As moneyness moves further out of the money, both average returns and standard deviations decrease.

Examining the returns by individual legs, we notice results similar to those from the weekly rebalancing scheme. On average, most of the profits are from the short put legs, which echoes the theoretical predictions. The short call legs, in contrast, compensate option buyers for absorbing delta exposure.

Table 7 also presents the Greeks at initiation and rollover days. From Panel B, we notice the increased delta exposure of short straddle and 3% and 5% short strangle strategies from initiation to rollover dates. The delta exposures of 7% short strangle strategies, on the other hand, decrease slightly on average over the monthly holding periods.

From Panel C, we can see clearly that the worsened delta-risk exposures are from the short call legs for almost all strategies except 7% out-of-the-money short strangle. Aligned with that, we also notice the increased gamma exposures, which contribute to the increases in delta exposure. Once again these increases mostly come from the short call legs. As for theta, the short put legs contribute a higher initial collection of time decay in the strangle strategies. For the short straddle strategy, however, theta is higher for the short call leg versus the short put leg. Moreover, as we would expect, when comparing the average theta between the initiation date and the rollover date, the speed of time decay increases for both legs of all the strategies.

5. The Effects of the Covid-19 Crash of 2020

5.1 Tests of Strategy Performance

We conduct tests using an extended dataset running from January 2020 through February 2021. This time period is a particularly harsh one in which to test the performance of short option strategies. During this time period, there was a major stock market crash between February 2020 and April 2020 and a strong subsequent recovery. Knowing these facts ahead of time means that one would expect holding short positions in puts during the crash and holding short positions in calls during the fast recovery would stress test the option strategies that we study. Nevertheless, we test how the selected short-dated option writing strategies performed during this time.[17]

Table 8 contains the monthly percentage returns from the selected option writing strategies from both the monthly and weekly trading schemes. All strategies, from either the monthly or weekly trading schemes, produce negative returns, on average. This unusual time period featured a one-month decline of 34% in the S&P 500 Index, followed by a two-month rally of 36%, using daily closing levels of the S&P 500 Index. During this volatile period, we might expect the short straddle and the short strangle to perform poorly–after all, they have uncapped losses from short puts and short calls. But this three-month period is only part of the 14 months in the extended sample.

We examine the performance of two strategies designed to provide insurance to the short straddle from big movements in the underlying. The first strategy is called the Crash-Neutral Short Straddle, created by adding a long position in a 10% out-of-the-money put option. The second strategy is called the Long Iron Butterfly, created by adding a long position in a 10% out-of-the-money call option to the Crash-Neutral Short Strangle.[18]

Similarly, we examine the performance of two strategies designed to provide insurance

[17] In this section, we omit the results using the short guts strategy because of its previous poor performance after incorporating transaction costs.

[18] Note that the Long Iron Butterfly uses calls and puts, whereas a traditional Long Butterfly consists of long and short positions in calls only or puts only.

to the short strangle from big movements in the underlying. The first strategy is called the Crash-Neutral Short Strangle, created by adding a long position in a 10% out-of-the-money put option. The second strategy is called the Long Iron Condor, created by adding a long position in a 10% out-of-the-money call option to the Crash-Neutral Short Strangle.

From the monthly trading scheme, the short strangle strategy generates losses of -5.88%, on average, using bid and ask prices over 14 months. As highlighted in Figure 4, the losses were concentrated between February 2020 through May 2020. During these months, the short strangle losses were -57.11%, -63.72%, -28.74%, and -28.18%, and the change in the underlying S&P 500 Index levels exceeded 10% each month. The changes of S&P 500 index were -10.68%, -16.27%, 13.74%, and 12.83%, respectively, from February through May. The insurance against sharp downward or short upward movements did not result in positive returns. The reason is that the insurance was designed to protect against major changes in the underlying. The insurance only kicked in when the underlying index changed by more than 10%. In other words, whenever the insurance kicks in, traders automatically lock 10% losses. Considering the insurance premium already eroded the monthly option premium traders can collect, the actual returns may not cover the guaranteed 10% losses over the 14 months. The long iron condor strategy in the monthly trading scheme, however, did reduce the monthly loss to -2.97%, on average, compared to the -5.88% average loss in the short strangle strategy. Similarly, the long iron butterfly strategy in the monthly trading scheme, had less of an average loss, -4.12%, compared to the monthly average loss in the short straddle, -6.07%.

The weekly trading scheme, on the other hand, has a different story. The short strangle strategy performed the best but still had average monthly losses of -4.84%. The losses were concentrated in five weeks between February and April 2020, as well as two weeks in October 2020, when the S&P 500 Index changed by more than 5%—which exceeds the "buffer" provided by the strangle. Unlike the monthly trading scheme, the strategies employing crash insurance did not mitigate the losses. The "crash-neutral" strangle and the long iron condor strategies from the weekly trading scheme had losses of -7.75% and -6.70%, respectively, which are both higher than the uninsured short strangle strategy. In other words, as rebalancing frequency increases, the benefit of insurance diminishes. More important, the weekly trading scheme started to recover earlier than the monthly one. From Figure 4, the weekly short strangle cumulative profit stopped declining and resumed growth in May 2020, one month earlier than the monthly short strangle. Similarly, the short straddle strategy from the weekly trading scheme has an average monthly loss of -10.25%, whereas the "crash-neutral" straddle and the long iron butterfly strategies from the weekly trading scheme had losses of -11.98% and -11.02%, respectively.

The Covid-19 crash also drastically and negatively impacted the cumulative profits from option writing strategies. Figure 4 shows the cumulative returns of a one-thousand dollar investment from December 2010 through February 2021 for the monthly and weekly short strangle strategies, as well as S&P 500 Index.

From December 2010 through December 2019, the one-thousand dollars investment in the short strangle strategy grew to $24,009 and $10,868, respectively, from the monthly and weekly trading schemes, using the full bid-ask spread. For context, the same one-thousand-dollar investment in S&P 500 Index only grew to $2,645. From February 2020 through May 2020, however, the monthly and weekly trading schemes for the short strangle strategy lost 92% and 81%, respectively, of their past 10-year cumulative profits due to the 2020 Covid-19 Stock Market Crash. The cumulative profits were $2,023 and $2,140, respectively, from the monthly and weekly trading schemes for the short strangle strategy at the beginning of June 2020. The growth of cumulative profits was back to normal as the stock market rapidly recovered from the crash. At the end of February 2021, the one-thousand-dollar investment cumulative profits from the short strangle strategy were $4,682 and $3,178 from the monthly and weekly schemes. In other words, traders almost doubled their stakes in eight months right after the Covid-19 market crash using a short strangle strategy.

The Covid-19 crash also had a major impact on transaction costs. As implied volatility inflated the option prices, it naturally widened the bid-ask spread.

6. Hedging Lessons from the Covid-19 Crash and Market Rebound

The Covid-19 Market Crash and quick rebound was a particularly harsh period over which to test the performance of pre-specified option writing trading strategies placed in a robotic way over the time period. Actual traders have many choices under these market conditions. These traders can act quickly during the trading day to modify their positions. With our data, however, we have identified three strategies that a robotic trader can follow. We assume that closing prices reflect the opportunities for robotic traders. These strategies encompass a wide range of possibilities.

Keep the original position placed the previous Friday Table 8 shows the results from following this strategy from December 2010 through December 2019. This mechanical strategy was the one that we assumed traders used in our initial tests. This strategy serves as a baseline against which we can compare two other strategies.

When the original position shows a loss, close it and hold cash We call this strategy the Early Exit Strategy. Under this strategy, the trader calculates the intrinsic value of each option in the position and subtracts them from the option premium from the short positions. We name it implied profit or loss. If the difference is still greater than zero, the trader does nothing. After all, these options have European-style exercises. Once the current holdings produce an implied loss (i.e., the difference is less than zero), the trader closes the positions and absorbs the losses. Note that this loss will be greater than the implied loss because the ask prices used to close the original positions include a time value. After closing the position, the trader holds cash for the rest of the week.

Sell more options to recover dollar losses We call this strategy the Dollar Loss Recovery Strategy. In this strategy, still the first step the trader calculates the implied profit or loss of the original short positions. If the total intrinsic value is zero, the trader does nothing because these options have European-style exercise. Once the current holdings produce an implied loss, traders will sell additional at-the-money options with the same expiration date, and use the newly collected option premium to offset any exiting implied loss. The type of the new options written is determined by the direction of the underlying index moves on that trading day. To be specific, if the S&P 500 Index goes down on that day, extra call options will be sold to recover the loss from the original positions. Similarly, if the index goes up, put options will be used. Traders will repeat the same process the next trading day by calculating the implied profit or loss with the combined new positions (i.e., the original short call and put positions, plus any extra newly written call or put options). If the new positions again produce an implied loss, traders will follow the same rule above and sell new additional options. Traders will continue with the practices described above until expiration.

We explore what happens to traders if they follow these strategies over the Covid-19 Crash sample. In this way, we can recalculate the accumulated dollar returns for the short strangle position over the entire sample period.[19] Figure 5 plots the cumulative profits of a $1,000 investment since December 2019 using the S&P 500 Index, the weekly short strangle, and two hedging strategies described above, with the shadow emphasis on the Covid-19 market crash period.

Table 9 contains the results of the three strategies. The four columns on the left-hand side report the monthly returns of the S&P 500 Index, the unhedged weekly short strangle

[19]Clearly, there are many other strategies that a trader could follow. One strategy that would come to mind is to restore delta neutrality. In so doing, the trader restores the trade to where the trader has a profitable position at expiration. In the "Dollar Loss Recovery" hedging strategy, the trader tries to avoid a loss at expiration. A delta-neutral hedge requires many more options to trade. Note that, at initiation, the delta of the short straddle is approximately zero. Unhedged, the short straddle position will have a delta of $+1$, -1, or zero at expiration. Under the "Dollar Loss Recovery" hedge, the delta of the portfolio at expiration will be $+1$ or -1.

Another strategy traders could follow is to close one leg of the original position or add a new long leg. Here, the trader calculates the intrinsic value of each option in the position. If the intrinsic value is zero, the trader does nothing. If the intrinsic value is positive, the trader can either buy back the option that is now in-the-money or buy an out-of-the-money option. This strategy appears, at first, to be appealing. Suppose the underlying price has moved—in a short time—in a direction against one of the short legs. In this case, option premiums, say for the current 5% out-of-the-money options, might be quite expensive.

strategy, the Early Exit Strategy, and the Dollar Loss Recovery Strategy. The four columns on the right-hand side report the cumulative profits of a $1,000 investment since December 2010 using the S&P 500 Index and the weekly short strangle. The $1,000 investment had grown to $2,646 and $10,868 from the S&P 500 Index and the unhedged weekly short strangle strategy by the end of December 2019. The profits of the Early Exit Strategy and the Dollar Loss Recovery Strategy started to cumulate from the profit of the unhedged weekly short strangle strategy in December 2019.

After one last positive return in January 2020, traders using the (unhedged) weekly short strangle strategy had three consecutive months of large negative returns. By the end of April 2020, the investment value fell to $1,849. The unhedged weekly short strangle strategy resumed earning positive returns after the market crash and rapid rebound, except in October 2020. By the end of February 2021, the investment grew to $3,178, a geometric growth rate of 5.4% per month.

For the two hedging strategies, both of them improved the poor performance of the weekly short strangle strategy during the Covid-19 Crash sample. The Early Exit Strategy proved to be disastrous during March 2020, when this strategy lost 71.03%. The loss occurred because option premiums were inflated during this period, lifting the ask prices on both legs of the strangle, which makes it costly to close the positions early. But still, it reduced losses in the other two months. By the end of April 2020, the investment value fell only to $3,178, compared with the unhedged profits of $1,849. By the end of February 2021, the investment grew back to $4,867, 53% more than the unhedged weekly short strangle strategy.

By contrast, the Dollar Loss Recovery strategy preserved more capital[20], except in March 2020 when traders using this strategy lost 9.32%. Employing this strategy, the cumulative dollar profit grew from $10,868 at the end of December 2019 to $30,051 at the end of February 2021, 8.45 times higher than the cumulative profits of the unhedged weekly short strangle strategy, as well as a geometric growth rate of about 9.2%. Note that there were large

[20] Also note this strategy requires additional margin requirement to initiate because of the new short positions, which is quite capital-intensive in some extreme situations.

positive monthly returns in February 2020 and April 2020. In part this return stemmed from the sale of options with high premiums—premiums that reflect the high option-implied volatility during that time.

Note that the Dollar Loss Recovery hedge does not restore delta neutrality. The flat top in Panel B of Figure 1 is the area where the short strangle has a zero delta at expiration. Instead, the Dollar Loss Recovery hedge infuses enough cash to attempt to create a break-even position for the hedger. That is, in Figure 1 this strategy tries to put the position at the intersection of the horizontal axis and a leg of the trapezoid. At those points, delta will be approaching ± 1 as expiration nears, but a move in the underlying could render all options in the position out-of-the-money which would result in a zero delta.

We look at each day during the January 2020 through February 2021 period to employ the strategies above. There were eight weeks when the writers of the original weekly short strangle strategy held options with a positive intrinsic value. This positive intrinsic value signals that there could be a loss at expiration. Appendix Table B1 contains the details of the calculations of the eight weeks for when the early exit strategy and the dollar-loss recovery strategy were used. Although we examined each week in the crash sample, the Covid-19 stock market crash and rapid recovery between February and June 2020 had a big impact on a short strangle strategy.

In Table B1, the first three columns include the date, the levels of the S&P 500 Index, and the daily percentage changes of the index. The next column reports the original position's implied or realized profit or loss using the weekly trading scheme for the short strangle strategy. When these European options were still alive, the profit/loss column contains the implied profit or loss of the original position. When the option expires, the column contains the realized profit or loss of the original position. The next column reports the realized loss if traders close both short positions before the options expire. In other words, that is the realized losses of the Early Exit Strategy. We use the (unreported) ask prices, which contain time value and intrinsic value, to buy back the call and put options. The next two column reports the implied or realized profit or loss of the Dollar Loss Recovery strategy.

We first report the portfolio value that reflects the original position's implied profit or loss, plus the value of any options added subsequently. We then report the result of adding a new leg to the original position for each trading day during the week. The next six columns contain the number of contracts, the strike prices, and the bid prices of the call or put options that are used to construct the original positions and any option legs added. The last column reports the net margin required by the exchange to initiate the original short positions, as well as the additional margin when additional options are added to the original short strangle position. Throughout, we assume trades are at the closing bid and ask prices.

As an example, let's look at the first six dates of Table B1. On Friday's initiation, 2/21/2020, the premium received for the short strangle was \$1.00 (and only the put had a positive bid price). Thus, the trader receives \$100. The net margin per share is \$332.91, or $\$33,291$. There is no effect on the position as of the close on Monday, 2/22/2020.

On Tuesday, 2/25/2020, however, the S&P 500 index level of 3,128.21 renders the original put, with a strike of 3,170 in-the-money. Thus, the intrinsic value of this put option is \$41.79, but the implied loss of the short position is $-\$40.79$, because of the \$1.00 received at the initiation. If the trader exits early the loss for the week is \$60.85, because we assume the trader buys the options back at their ask price (which includes time value). Using the Dollar Loss Recovery Strategy, the trader would sell one at-the-money call option with a strike of 3,130 at the bid price of \$44.30. Thus, the portfolio value after this additional premium is received is $-\$40.79 + \$44.30$, which is \$3.51. The total margin for these three short options is \$800.35. Similarly, on Wednesday 2/26/2020, the 3,170 put moved \$11.82 more into the money. However because the trader had received an option premium of \$3.51 the previous day, the implied loss of the portfolio before hedging is $-\$8.31$, which signals another hedge. The trader sells an at-the-money with a strike of 3,120 for \$26.50, which yields an implied portfolio profit of \$18.19.

On Thursday, 2/27/2020, the 3,170 put option moved even more into the money, by

$137.63, yielding an implied loss of $-\$119.44$. If the trader sells 4 additional calls with a strike of 2,980 at $30.80 each, the implied profit of the combined positions after these additional legs is $-\$119.44 + (4 \times \$30.80) = \$3.76$. The 3,170 put moved $24.50 more into the money the next day, which yields a realized loss of $-\$20.78$ at expiration. Compared with the original weekly short strangle strategy, the unhedged trader's realized loss for the week was $-\$214.78$. Note that after the last hedges on Thursday, the total margin is $\$3,046.50$ per share, or $\$304,650$. The details for the other weeks are shown in the remaining rows of Table B1.

7. Concluding Remarks

The Options Clearing Corporation (OCC), cleared 9.87 billion options contracts in 2021—a 32.1 percent increase compared to the previous record in 2020.[21] In 2021 the New York Times stated, "Much of this money has come from small-time traders, often with little experience, hoping to make fast gains by buying "calls"— bets on rising markets set to expire quickly."[22]

These small-time options traders might be thinking that "time is on my side," with respect to underlying price movements. Perhaps traders who sold these options also felt that time was on their side. But whose side is time on, really, and what role does it play?

The existing literature on the performance of option writing strategies does not have a theoretical or empirical study of how best to capture theta effects. We fill the gap between the performance of option writing strategies and the effect of the nonlinear nature of options' time value decay. Using data from December 2010 to December 2019, our paper is the first to look at optimal strategies to capture time decay using short-dated options.

Academics and professional traders know that options are decaying assets. Although our empirical results do not require the Black and Scholes (1973) assumptions, a familiar

[21]The OCC, the world's largest equity derivatives clearing organization, cleared 9.87 billion option contracts in 2021. https://www.businesswire.com/news/home/20220104005239/en/OCC-Clears-Record-Setting-9.93-Billion-Total-Contracts-in-2021

[22]How Options Trading Could Be Fueling a Stock Market Bubble. https://www.nytimes.com/2021/01/25/business/stocks-options-bubble.html

way to think about the speed of time decay is by using theta, Θ, the partial derivative of the Black and Scholes (1973) option pricing model with respect to time. Although time is deterministic, theta is not constant. Theta varies by the level of volatility, option moneyness, and is nonlinear as options near expiration.

At-the-money options have the highest Black and Scholes (1973) thetas across all moneyness levels. These thetas increase monotonically at an increasing rate and peak at expiration. These options have the highest gamma exposure, which increases as the time to expiration decreases. This exposure is intuitive because the delta will be -1, 0, or 1 at expiration, depending on the option writing strategy. By contrast, the in- and out-of-the-money options have a lower theta that peaks early and then decreases as expiration nears.

Thus, theoretically, option writers might be able to capture the most time decay in at-the-money option strategies with a short time to expiration. Importantly, these Theta movements depend on the *ceteris paribus* assumption that neither the underlying asset price nor the forward-looking volatility will change. We find, however, that changes in the underlying asset price during the week before expiration affect profits from option trading strategies.

Using S&P 500 Index options, Coval and Shumway (2001) explore returns to a long straddle strategy. Coval and Shumway (2001) find that buyers of this strategy lose about 3% per week, so they conclude option sellers should profit. Using the negative of the dollar losses from a long straddle is appropriate to measure the dollar losses from a short straddle. This approach is problematic when calculating percentage returns, so we use a margin-based approach to calculate the percentage returns and the risk-adjusted performance of option writing strategies.

Jackwerth (2000), Coval and Shumway (2001), Bakshi and Kapadia (2003), and Jones (2006) find that option writing strategies offer substantial returns and Sharpe ratios. For example, Coval and Shumway (2001) find traders could earn about 3% per week on "crash-neutral" short straddles. Santa-Clara and Saretto (2009) find that the monthly returns of short straddles and 10% OTM strangles are 11.5% and 51%, respectively. Using short-dated S&P 500 Index options, we find that the short straddle strategy earned from 0.2% to 1.9% per month, even after accounting for the bid-ask spread. The short 5% OTM strangle strategy, however, earned from 2.3% to 3.4% per month, and had the best risk-adjusted performance.

On a risk-adjusted basis, we find that a weekly trading scheme with a short strangle strategy using short-dated, near-expiration index options produced the highest performance measure, in general. On a raw return basis, however, the short strangle strategy with monthly rebalancing and longer time to maturity generated the highest cumulative profits.

We also conduct tests using data from January 2020 to February 2021. This sample period is a particularly interesting one because there was a short, and substantial, market crash and recovery during that period. The Covid-19 market crash and the strong subsequent recovery that happened between February 2020 and April 2020 had a strong negative impact on all the strategies we test.

Jackwerth (2000) reports that selling at-the-money puts yields risk-adjusted excess returns, even when simulating a crash every four years. We find the actual Covid-19 Market Crash and subsequent recovery resulted in negative average returns for the short straddle and the short strangle—although the short strangle strategy had positive returns in eight of the 14 months. Using weekly returns, we also find negative average returns for the short straddle and the short strangle. The losses for the strangle were concentrated in five of the 60 weeks. During these weeks, the S&P 500 Index changed by more than 7.5%—which exceeds the "buffer" level provided by the 5% OTM strangle. Over the Covid-19 crash period, however, we find that traders who implemented a straightforward novel hedging strategy maintained and grew their trading capital.

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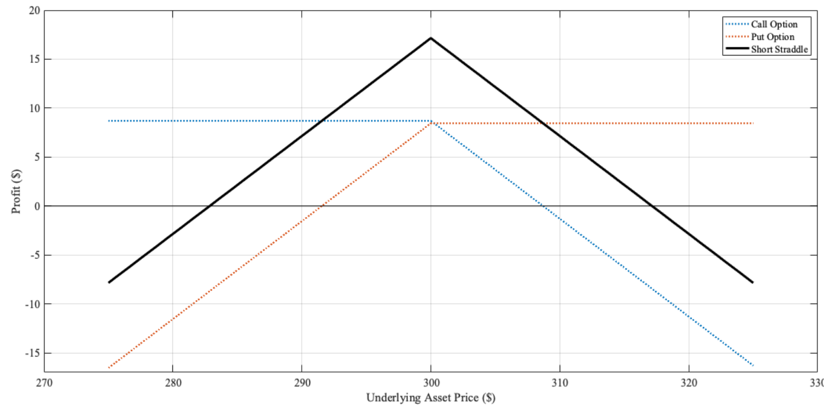
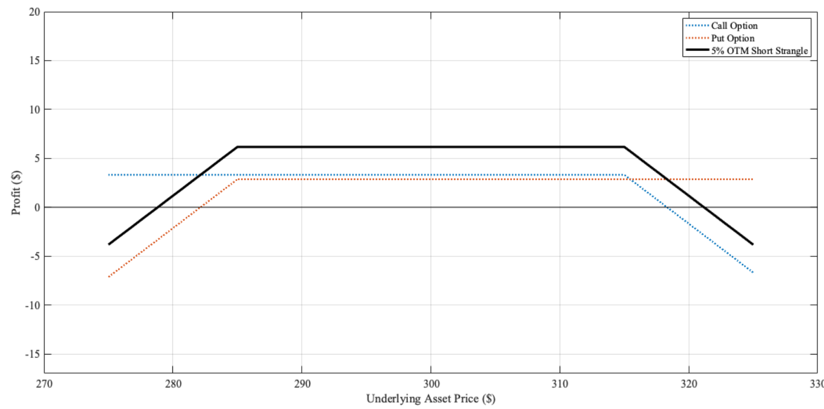
Panel A. Short Straddle



Panel B. Short Strangle



Panel C. All Five Option Writing Strategies

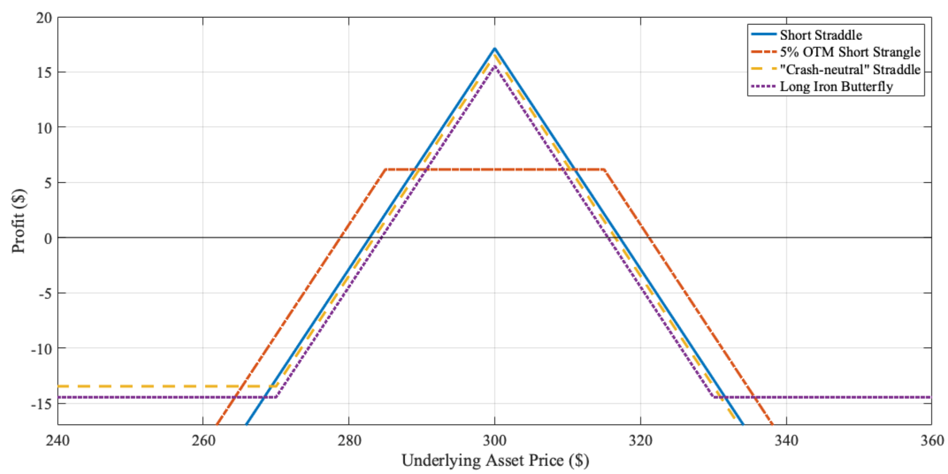


Figure 1: Payoff Profiles for Five Option Writing Strategies. We omit the short guts strategy because it has a payoff diagram similar to the short strangle strategy. To compute the maximum payoff amount, we use the Black-Scholes model with a stock price of $300, strike price of the at-the-money options is $300, the strike prices of the out-of-the-money call and put option are $315 and $285, respectively, an implied volatility of 25%, a risk-free rate of 1%, and 30 days to expiration.

Constructing The Monthly Trading Scheme and the Weekly Trading Scheme

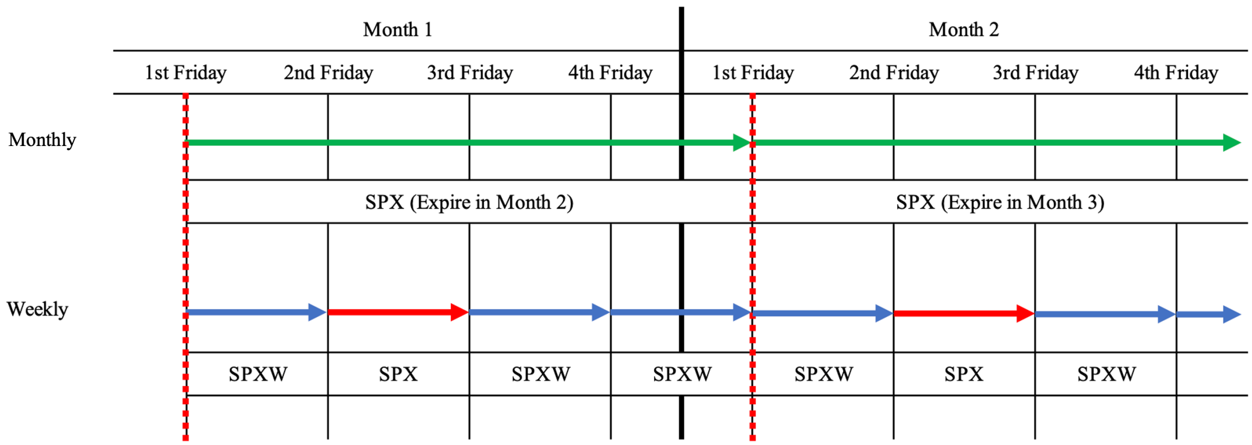


Figure 2: Holding Period Details. This figure displays the construction of the holding period and the rebalancing process for the monthly trading scheme and the weekly trading scheme. On the first Friday of each month, traders construct the monthly trading scheme by writing standard SPX options that expire the following month. They will hold the short positions until the first Friday of the next month and close out their position. Traders construct the trading scheme by writing SPXW weekly options on a Friday that expires the following Friday. Traders hold the weekly options until expiration and repeat the same procedure every week.

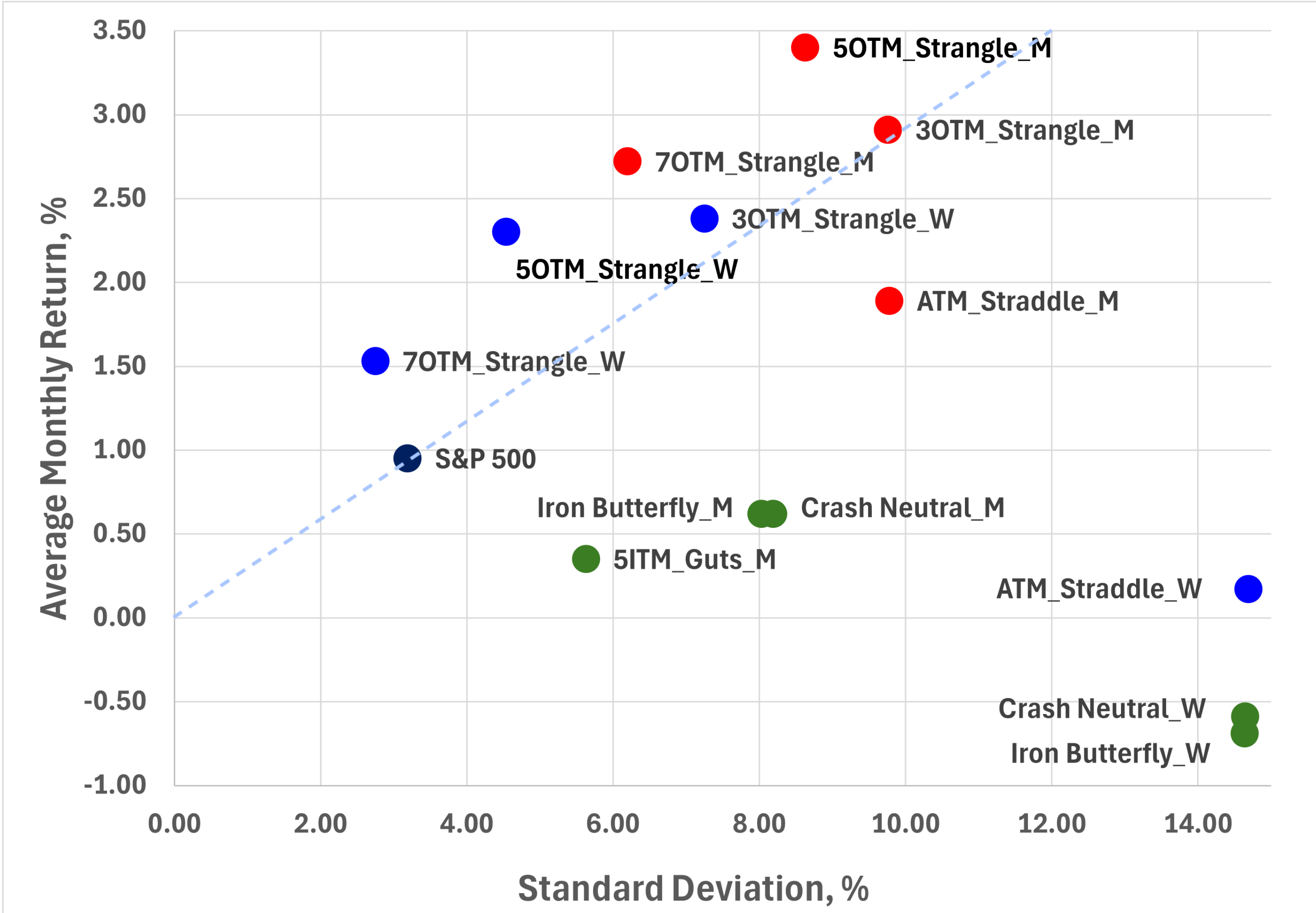


Figure 3: Average Monthly Return and Standard Deviation, from December 2010 through December 2019.
This figure displays the average monthly return and standard deviation for the S&P 500 and for two different rebalancing schemes: Monthly–denoted with an "M" and weekly–denoted with a "W." For each scheme, there are four option writing strategies: an at-the-money straddle, (ATM_Straddle), 3% out-of-the-money strangle, (3OTM_Strangle), 5% out-of-the-money strangle, (5OTM_Strangle), and 7% out-of-the-money strangle, (7OTM_Strangle).

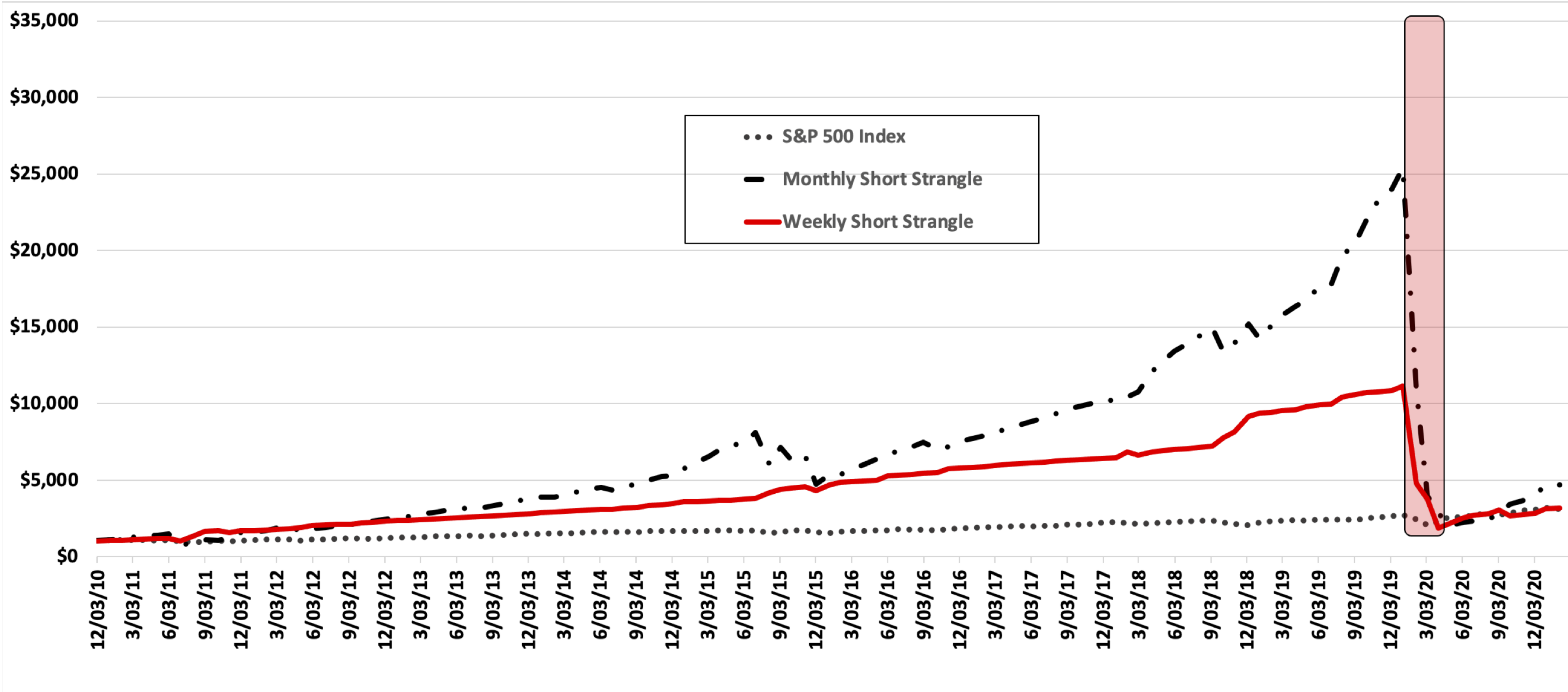


Figure 4: Cumulative Profits of A One-thousand Dollars Investment from December 2010 through February 2021. This figure displays the cumulative profits, in dollars, from the short strangle strategy for both the monthly and weekly trading schemes, as well as S&P 500 Index, assuming traders invest one thousand dollars at the beginning of the sample period, December 3, 2010. From December 2010 through December 2019, the one-thousand-dollar investment in the short strangle strategy grew to $24,009 and $10,868, respectively, from the monthly and weekly trading schemes, using the full bid-ask spread. For context, the same one-thousand-dollar investment in S&P 500 Index only grew to $2,645. From February 2020 through May 2020, however, the monthly and weekly trading schemes short strangle strategy lost 92% and 81%, respectively, of their past 10-year cumulative profits, due to the 2020 Covid-19 Stock Market Crash. The cumulative profits were $2,023 and $2,140, respectively, from the monthly and weekly trading schemes short strangle strategy, at the beginning of June 2020. The growth of cumulative profits was back to normal as the stock market rapidly recovered from the crash. At the end of February 2021, the one-thousand-dollar investment cumulative profits from the short strangle strategy were $4,682 and $3,178 from the monthly and weekly schemes.

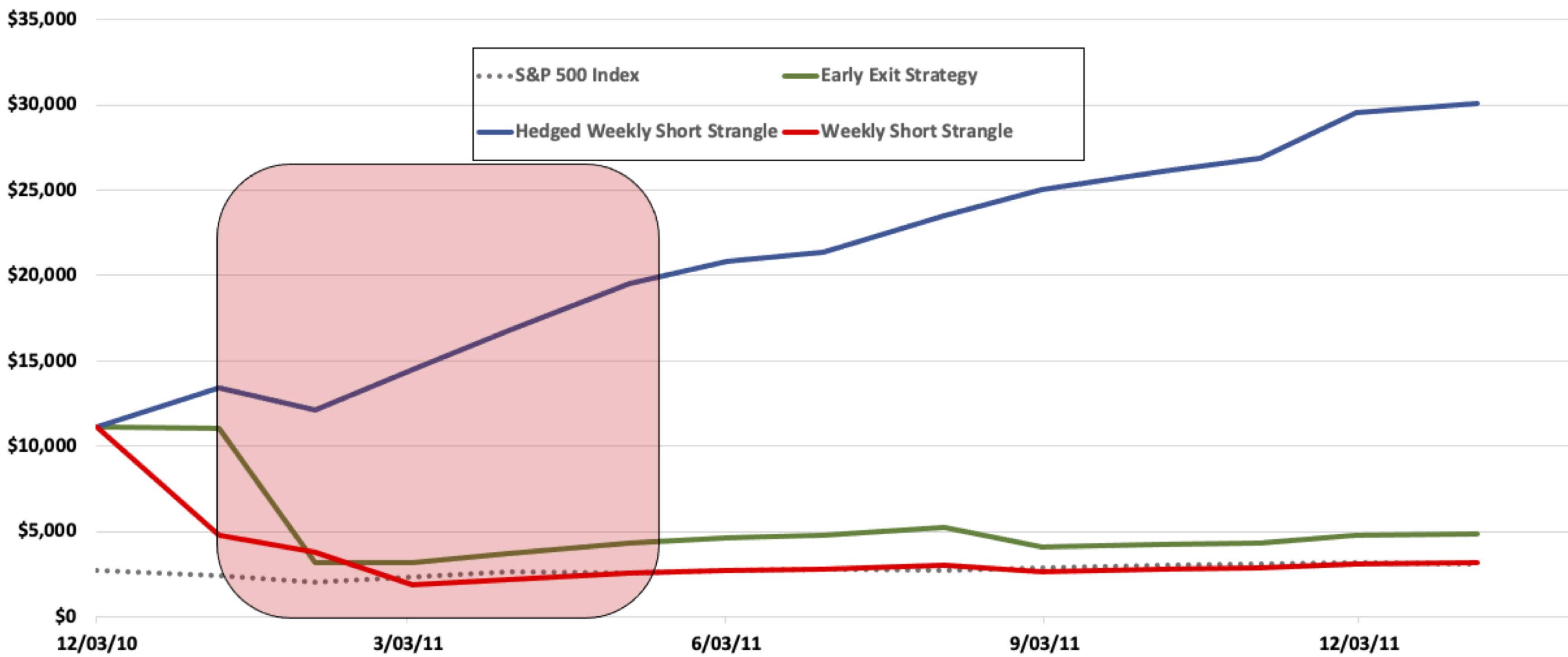


Figure 5: Hedged Strategy Cumulative Profits from December 2010 through February 2021.
This figure displays the cumulative profits, in dollars, from the weekly trading scheme short strangle, both the original and the hedged strategies, as well as S&P 500 Index, assuming traders invest one thousand dollars at the beginning of the sample period, December 3, 2010. As mentioned earlier in Figure 3, the weekly trading schemes short strangle strategy lost 81% of its past 10-year cumulative profits due to the 2020 Covid-19 Stock Market Crash. With a simple hedging strategy, the cumulative profits of the short strangle strategy kept growing during the 2020 Covid-19 Stock Market Crash. At the end of February 2021, the one-thousand-dollar investment cumulative profits from the hedged short strangle strategy were $30,050.

Table 1: List of Strategies
This table provides the full list of strategies and the components of each strategy in the paper.

Strategy	Components			
Short Straddle		Short ATM Call	Short ATM Put	
Short Strangle		Short OTM Call	Short OTM Put	
Short Guts		Short ITM Call	Short ITM Put	
"Crash-neutral" Straddle	Long Deep OTM Put	Short ATM Call	Short ATM Put	
Long Iron Butterfly	Long Deep OTM Put	Short ATM Call	Short ATM Put	Long Deep OTM Call

Table 2: Monthly Dollar Returns, per Share Optioned.
This table contains summary statistics of monthly dollar returns per share optioned from five option writing strategies for both the monthly and the weekly trading schemes. Panel A presents the mean, standard deviation, skewness, and excess kurtosis, as well as 1st percentile, 25th percentile, 50th percentile, 75th percentile, and 99th percentile of the dollar returns using the midpoints of the bid-ask spread. The results on the top use the monthly trading scheme, while the ones on the bottom use the weekly trading scheme. Panel B presents similar information for monthly dollar returns using the bid and ask prices.

Panel A. Using Midpoints of Bid-Ask Spread

A1. The Monthly Trading Scheme

	ATM Short Straddle	Crash Neutral Short Straddle	Long Iron Butterfly	3% OTM Short Strangle	5% OTM Short Strangle	7% OTM Short Strangle	5% ITM Short Guts
Number of Months	109	109	109	109	109	109	109
Mean ($)	8.72	4.48	4.19	8.80	8.09	6.50	7.91
Standard Deviation ($)	27.51	24.70	24.48	20.51	14.51	9.72	14.51
Skewness	−1.56	−1.37	−1.40	−1.99	−2.29	−2.35	−2.26
Excess Kurtosis	3.97	2.72	2.86	6.55	8.93	10.96	8.79
1 Percentiles ($)	−88.93	−73.93	−74.15	−73.65	−55.00	−32.80	−55.50
25 Percentiles ($)	−2.20	−8.05	−8.15	3.63	6.50	4.65	6.20
50 Percentiles ($)	12.10	8.82	8.77	11.63	9.43	6.80	9.35
75 Percentiles ($)	27.95	24.58	23.20	17.23	13.35	9.53	13.15
99 Percentiles ($)	56.10	41.98	41.75	46.80	34.60	27.18	34.20

A2. The Weekly Trading Scheme

	ATM Short Straddle	Crash Neutral Short Straddle	Long Iron Butterfly	3% OTM Short Strangle	5% OTM Short Strangle	7% OTM Short Strangle	5% ITM Short Guts
No. of Synthetic Months	109	109	109	109	109	109	109
Mean ($)	3.90	2.27	2.11	6.63	5.23	3.43	5.15
Standard Deviation ($)	48.81	49.11	49.13	15.74	6.90	4.11	7.01
Skewness	−1.66	−1.68	−1.68	−1.52	2.33	3.63	2.43
Excess Kurtosis	4.40	4.38	4.39	5.85	10.06	15.02	10.98
1 Percentiles ($)	−149.23	−153.58	−153.83	−49.64	−7.94	0.68	−8.17
25 Percentiles ($)	−8.30	−9.84	−9.94	4.93	2.38	1.45	2.35
50 Percentiles ($)	11.10	8.64	8.54	7.20	3.48	2.15	3.40
75 Percentiles ($)	33.42	32.45	32.32	10.58	5.60	3.50	5.50
99 Percentiles ($)	84.83	82.48	82.31	43.05	30.90	25.18	30.45

Table 2, Continued.

Panel B. Using Bids and Asks

B1. The Monthly Trading Scheme

	ATM Short Straddle	Crash Neutral Short Straddle	Long Iron Butterfly	3% OTM Short Strangle	5% OTM Short Strangle	7% OTM Short Strangle	5% ITM Short Guts
Number of Months	109	109	109	109	109	109	109
Mean ($)	5.10	1.55	1.54	6.64	6.52	5.17	0.77
Standard Deviation ($)	27.58	24.68	24.45	20.75	14.67	9.86	14.53
Skewness	−1.61	−1.36	−1.39	−2.11	−2.50	−2.63	−2.26
Excess Kurtosis	4.11	2.68	2.83	6.87	9.56	11.92	8.12
1 Percentiles ($)	−94.55	−77.55	−77.50	−78.65	−58.10	−35.35	−60.90
25 Percentiles ($)	−6.70	−10.20	−10.35	2.05	5.20	3.55	−2.50
50 Percentiles ($)	8.40	5.10	5.40	9.60	8.05	5.60	3.30
75 Percentiles ($)	24.50	21.45	20.20	15.95	11.70	8.60	7.10
99 Percentiles ($)	49.60	38.90	38.95	44.70	32.80	24.00	27.30

B2. The Weekly Trading Scheme

	ATM Short Straddle	Crash Neutral Short Straddle	Long Iron Butterfly	3% OTM Short Strangle	5% OTM Short Strangle	7% OTM Short Strangle	5% ITM Short Guts
No. of Synthetic Months	109	109	109	109	109	109	109
Mean ($)	−1.12	−3.19	−3.48	5.03	4.21	2.66	−16.42
Standard Deviation ($)	49.02	49.53	49.58	15.53	6.21	3.51	12.65
Skewness	−1.66	−1.67	−1.67	−1.85	1.82	3.66	−0.17
Excess Kurtosis	4.38	4.28	4.29	6.27	8.45	14.72	1.36
1 Percentiles ($)	−156.38	−161.23	−161.73	−51.61	−10.12	0.40	−46.00
25 Percentiles ($)	−14.73	−16.28	−16.53	4.05	1.95	1.05	−21.90
50 Percentiles ($)	6.05	5.53	5.33	6.10	2.85	1.60	−13.30
75 Percentiles ($)	29.33	27.88	27.63	9.25	4.67	2.70	−9.00
99 Percentiles ($)	80.23	77.48	77.13	39.95	29.15	20.65	14.90

Table 3: Monthly Percentage Returns Using the Net Margin Approach.
This table contains summary statistics of monthly percentage returns using the net margin approach from five option writing strategies for both the monthly and the weekly trading schemes. Panel A presents the mean, standard deviation, skewness, and excess kurtosis, as well as 1st percentile, 25th percentile, 50th percentile, 75th percentile, and 99th percentile of the monthly percentage returns using the midpoints of the bid-ask spread. The results on the top use the monthly trading scheme, while the ones on the bottom use the weekly trading scheme. Panel B presents similar information for monthly percentage returns using the bid and ask prices.

Panel A. Using Midpoints of Bid-Ask Spread

A1. The Monthly Trading Scheme Net Margin Approach

	ATM Short Straddle	Crash Neutral Short Straddle	Long Iron Butterfly	3% OTM Short Strangle	5% OTM Short Strangle	7% OTM Short Strangle	5% ITM Short Guts
Number of Months	109	109	109	109	109	109	109
Mean (%)	3.22	1.66	1.55	3.97	4.35	3.53	2.81
Standard Deviation (%)	9.85	8.26	8.11	9.76	8.69	6.27	5.72
Skewness	−1.56	−1.30	−1.39	−1.90	−2.19	−1.75	−2.08
Excess Kurtosis	5.26	2.62	2.89	8.54	12.50	14.25	11.76
1 Percentiles (%)	−32.93	−28.13	−28.30	−32.43	−26.56	−15.79	−17.69
25 Percentiles (%)	−0.86	−2.63	−2.72	1.39	3.02	2.25	1.78
50 Percentiles (%)	3.99	2.61	2.59	4.95	4.96	3.34	3.16
75 Percentiles (%)	8.73	7.05	6.94	7.28	6.88	4.97	4.39
99 Percentiles (%)	23.23	13.95	13.04	27.33	27.87	22.58	18.30

A2. The Weekly Trading Scheme Net Margin Approach (Weekly returns are multiplied into months to align with the monthly results)

	ATM Short Straddle	Crash Neutral Short Straddle	Long Iron Butterfly	3% OTM Short Strangle	5% OTM Short Strangle	7% OTM Short Strangle	5% ITM Short Guts
No. of Synthetic Months	109	109	109	109	109	109	109
Mean (%)	2.08	1.46	1.40	3.21	2.96	2.00	1.91
Standard Deviation (%)	15.02	14.88	14.84	7.71	5.44	3.34	3.52
Skewness	−0.62	−0.70	−0.71	0.01	4.45	5.42	4.48
Excess Kurtosis	1.02	0.99	0.98	7.82	30.31	32.40	30.36
1 Percentiles (%)	−39.37	−40.39	−40.23	−21.78	−6.66	0.37	−3.57
25 Percentiles (%)	−3.97	−4.59	−4.64	1.78	1.07	0.66	0.64
50 Percentiles (%)	3.04	2.87	2.83	2.99	1.81	1.03	1.21
75 Percentiles (%)	10.65	10.01	9.95	5.24	3.10	1.99	2.30
99 Percentiles (%)	36.48	30.46	30.36	20.50	26.40	23.75	17.21

Table 3, Continued.

Panel B. Using Bids and Asks

B1. The Monthly Trading Scheme Net Margin Approach

	ATM Short Straddle	Crash Neutral Short Straddle	Long Iron Butterfly	3% OTM Short Strangle	5% OTM Short Strangle	7% OTM Short Strangle	5% ITM Short Guts
Number of Months	109	109	109	109	109	109	109
Mean (%)	1.89	0.62	0.62	2.91	3.40	2.72	0.35
Standard Deviation (%)	9.78	8.19	8.03	9.76	8.63	6.20	5.63
Skewness	−1.75	−1.34	−1.41	−2.24	−2.69	−2.45	−2.44
Excess Kurtosis	5.86	2.64	2.91	9.71	14.49	17.14	12.77
1 Percentiles (%)	−34.29	−29.13	−28.99	−33.78	−28.06	−17.02	−19.41
25 Percentiles (%)	−2.20	−3.11	−3.12	0.66	2.58	1.82	−0.82
50 Percentiles (%)	2.85	1.98	2.02	4.12	4.06	2.75	0.98
75 Percentiles (%)	7.93	6.12	6.11	6.32	6.03	4.32	2.34
99 Percentiles (%)	20.52	12.22	12.14	24.65	24.16	20.91	14.71

B2. The Weekly Trading Scheme Net Margin Approach (Weekly returns are multiplied into months to align with the monthly results)

	ATM Short Straddle	Crash Neutral Short Straddle	Long Iron Butterfly	3% OTM Short Strangle	5% OTM Short Strangle	7% OTM Short Strangle	5% ITM Short Guts
No. of Synthetic Months	109	109	109	109	109	109	109
Mean (%)	0.17	−0.59	−0.69	2.38	2.30	1.53	−5.06
Standard Deviation (%)	14.69	14.65	14.64	7.25	4.54	2.75	4.08
Skewness	−0.71	−0.77	−0.78	−0.90	3.48	5.45	1.44
Excess Kurtosis	0.98	0.97	0.97	6.15	24.71	32.59	9.09
1 Percentiles (%)	−41.35	−43.12	−43.31	−23.56	−8.08	0.20	−12.86
25 Percentiles (%)	−6.11	−6.69	−6.81	1.49	0.90	0.48	−7.03
50 Percentiles (%)	1.76	1.21	1.15	2.63	1.49	0.77	−4.51
75 Percentiles (%)	8.69	8.49	8.43	4.29	2.52	1.59	−3.46
99 Percentiles (%)	28.03	26.90	26.78	18.96	19.97	18.98	7.68

Table 4: Risk-Adjusted Performance for Monthly Returns.
This table contains results from four performance measures using monthly returns: the Sharpe ratio, the Sortino ratio, Leland's alpha, and the Ingersoll et al. (2007) manipulation-proof performance measures (MPPM). Panel A presents the performance of the five strategies using the midpoints of the bid-ask spread. The results on the top use the monthly trading scheme, while the ones on the bottom use the weekly trading scheme. Panel B presents the same measures using the bid and ask prices.

Panel A. Using Midpoints of Bid-Ask Spread

A1. The Monthly Trading Scheme Net Margin Approach

	ATM Short Straddle	Crash Neutral Short Straddle	Long Iron Butterfly	3% OTM Short Strangle	5% OTM Short Strangle	7% OTM Short Strangle	5% ITM Short Guts
Sharpe ratio	0.32	0.20	0.19	0.40	0.49	0.56	0.48
Sortino ratio	0.47	0.27	0.25	0.58	0.72	0.86	0.70
Leland's alpha (%)	2.03	0.91	0.77	2.52	2.80	2.38	1.78
MPPM ($\rho = 2$)	0.24	0.10	0.09	0.32	0.39	0.36	0.28
MPPM ($\rho = 3$)	0.15	0.05	0.04	0.22	0.31	0.33	0.26
MPPM ($\rho = 4$)	0.04	−0.01	−0.02	0.09	0.20	0.29	0.23

A2. The Weekly Trading Scheme Net Margin Approach

	ATM Short Straddle	Crash Neutral Short Straddle	Long Iron Butterfly	3% OTM Short Strangle	5% OTM Short Strangle	7% OTM Short Strangle	5% ITM Short Guts
Sharpe ratio	0.14	0.10	0.09	0.41	0.54	0.58	0.53
Sortino ratio	0.19	0.13	0.13	0.68	2.01	N/A	2.05
Leland's alpha (%)	0.30	−0.38	−0.44	2.60	2.93	2.19	1.87
MPPM ($\rho = 2$)	−0.07	−0.14	−0.15	0.30	0.32	0.22	0.21
MPPM ($\rho = 3$)	−0.26	−0.33	−0.34	0.27	0.30	0.22	0.20
MPPM ($\rho = 4$)	−0.47	−0.55	−0.56	0.22	0.29	0.21	0.20

Table 4, Continued.

Panel B. Using Bids and Asks

B1. The Monthly Trading Scheme Net Margin Approach

	ATM Short Straddle	Crash Neutral Short Straddle	Long Iron Butterfly	3% OTM Short Strangle	5% OTM Short Strangle	7% OTM Short Strangle	5% ITM Short Guts
Sharpe ratio	0.19	0.07	0.07	0.29	0.39	0.43	0.05
Sortino ratio	0.25	0.09	0.09	0.39	0.52	0.61	0.07
Leland's alpha (%)	0.68	−0.12	−0.15	1.44	1.83	1.56	−0.69
MPPM ($\rho = 2$)	0.08	−0.02	−0.02	0.19	0.28	0.26	−0.01
MPPM ($\rho = 3$)	−0.02	−0.08	−0.07	0.07	0.18	0.23	−0.04
MPPM ($\rho = 4$)	−0.14	−0.13	−0.13	−0.08	0.05	0.18	−0.07

B2. The Weekly Trading Scheme Net Margin Approach

	ATM Short Straddle	Crash Neutral Short Straddle	Long Iron Butterfly	3% OTM Short Strangle	5% OTM Short Strangle	7% OTM Short Strangle	5% ITM Short Guts
Sharpe ratio	0.01	−0.04	−0.05	0.32	0.50	0.54	−1.25
Sortino ratio	0.01	−0.05	−0.06	0.47	1.40	N/A	−0.82
Leland's alpha (%)	−1.62	−2.45	−2.55	1.72	2.24	1.69	−5.17
MPPM ($\rho = 2$)	−0.29	−0.39	−0.40	0.21	0.25	0.17	−0.65
MPPM ($\rho = 3$)	−0.49	−0.59	−0.60	0.17	0.24	0.17	−0.66
MPPM ($\rho = 4$)	−0.71	−0.82	−0.83	0.15	0.23	0.16	−0.67

Table 5: Weekly Percentage Returns from Other Weeks to Expiration.
This table contains summary statistics of the weekly percentage returns from the two option writing strategies from alternative weekly trading scheme designs. Specifically, we explore whether holding the SPXW weekly options two weeks, three weeks, ... , six weeks from expiration would improve the profit of the weekly trading scheme. Panel A presents the mean, standard deviation, skewness, and excess kurtosis, as well as 1st percentile, 25th percentile, 50th percentile, 75th percentile, and 99th percentile of the short straddle strategy. The results on the left-hand side are generated using the midpoints of the bid-ask spread, while the ones on the right-hand side use bid and ask prices to incorporate transaction costs. Panel B presents the same weekly return statistics for the short strangle strategy.

Panel A. The Short Straddle Strategy

	Using Midpoints of Bid-Ask Spread						Using Bids and Asks					
	1 Week	2 Weeks	3 Weeks	4 Weeks	5 Weeks	6 Weeks	1 Week	2 Weeks	3 Weeks	4 Weeks	5 Weeks	6 Weeks
Number of Weeks	311	311	311	311	311	311	311	311	311	311	311	311
Mean (%)	0.06	0.28	0.13	0.13	0.30	0.30	−0.24	−0.43	−0.58	−0.58	−0.44	−0.46
Standard Deviation (%)	6.91	5.53	4.86	4.44	4.08	3.81	6.90	5.67	5.00	4.57	4.21	3.95
Skewness	−1.21	−2.42	−2.67	−2.72	−2.60	−2.55	−1.24	−2.49	−2.76	−2.79	−2.75	−2.62
Excess Kurtosis	2.76	8.16	9.71	10.07	9.19	8.97	2.71	8.31	10.04	10.41	9.95	9.22
1 Percentiles (%)	−21.23	−24.89	−22.39	−20.41	−18.72	−17.52	−21.64	−26.21	−24.87	−21.92	−20.16	−18.67
25 Percentiles (%)	−2.97	−0.87	−0.70	−0.64	−0.50	−0.50	−3.27	−1.52	−1.43	−1.33	−1.06	−1.18
50 Percentiles (%)	1.44	1.71	1.38	1.20	1.34	1.19	1.16	1.06	0.88	0.61	0.68	0.52
75 Percentiles (%)	4.52	3.36	2.79	2.57	2.52	2.36	4.11	2.76	2.20	1.89	1.87	1.63
99 Percentiles (%)	13.23	8.99	6.75	6.26	6.01	5.76	12.79	7.52	5.85	5.32	4.64	4.82

Panel B. The Short Strangle Strategy

	Using Midpoints of Bid-Ask Spread						Using Bids and Asks					
	1 Week	2 Weeks	3 Weeks	4 Weeks	5 Weeks	6 Weeks	1 Week	2 Weeks	3 Weeks	4 Weeks	5 Weeks	6 Weeks
Number of Weeks	311	311	311	311	311	311	311	311	311	311	311	311
Mean (%)	0.53	0.49	0.41	0.40	0.51	0.52	0.44	0.24	0.07	−0.02	0.00	−0.04
Standard Deviation (%)	1.11	2.96	3.57	3.89	4.04	4.19	1.04	3.01	3.62	3.96	4.10	4.28
Skewness	−0.36	−3.63	−3.46	−3.17	−2.87	−2.73	−1.24	−4.01	−3.67	−3.36	−3.08	−2.91
Excess Kurtosis	26.91	23.45	18.56	15.09	12.23	10.97	30.81	25.54	19.66	16.16	13.34	11.85
1 Percentiles (%)	0.07	−12.99	−16.69	−17.90	−17.94	−18.08	0.04	−13.46	−17.21	−18.48	−19.04	−19.01
25 Percentiles (%)	0.19	0.32	0.22	0.11	0.11	0.12	0.14	0.18	−0.02	−0.25	−0.38	−0.35
50 Percentiles (%)	0.30	0.63	0.87	0.96	1.14	1.24	0.25	0.49	0.64	0.69	0.78	0.80
75 Percentiles (%)	0.52	1.20	1.59	1.93	2.32	2.53	0.43	0.99	1.28	1.58	1.76	1.93
99 Percentiles (%)	4.45	6.93	6.75	6.80	7.28	7.28	4.08	6.07	5.47	5.99	5.89	5.62

Table 6: Greeks of Each Weekly Strategy at Initiation and Expiration.
This table contains values for Theta, Gamma, and Delta at initiation of short straddles and short strangles for the 473 weeks in the sample. Statistics for four strategies are presented: the at-the-money straddle, and three strangles, 3%, 5%, and 7% out-of-the-money, respectively. Data for Delta values at expiration is also presented.

Panel A: Greek Values At Initiation of a Short Straddle and Short Strangles

	Straddle	**3% Strangle**			**5% Strangle**			**7% Strangle**		
	Average (Std. Dev.)	Average (Std. Dev.)	Decline (%) From Straddle	T-stat	Average (Std. Dev.)	Decline (%) From Straddle	T-stat	Average (Std. Dev.)	Decline (%) From Straddle	T-stat
Theta	1.9937	0.8559	-57.1%	-20.92	0.5049	-74.7%	-31.11	0.3393	-83.0%	-36.64
	(0.9245)	(0.7355)			(0.4756)			(0.3286)		
Short Call Leg	1.0196	0.2176			0.0852			0.0433		
Short Put Leg	0.9761	0.6383			0.4197			0.2960		
Gamma	-0.0262	-0.0056	-78.8%	48.10	-0.0021	-92.0%	57.68	-0.0010	-96.3%	60.86
	(0.0090)	(0.0025)			(0.0014)			(0.0007)		
Short Call Leg	-0.0131	-0.0022			-0.0006			-0.0002		
Short Put Leg	-0.0131	-0.0034			-0.0015			-0.0007		
Delta	0.0737	0.0585	-20.6%	-3.62	0.0335	-54.6%	-9.72	0.0196	-73.5%	-13.32
	(0.0865)	(0.0291)			(0.0245)			(0.0178)		
Short Call Leg	-0.4631	-0.0398			-0.0113			-0.0043		
Short Put Leg	0.5368	0.0984			0.0447			0.0239		

Panel B: Profits at Expiration and Delta Values at Expiration

	Straddle	**3% Strangle**			**5% Strangle**			**7% Strangle**		
	Average (Std. Dev.)	Average (Std. Dev.)	Increase (%) From Straddle	T-stat	Average (Std. Dev.)	Increase (%) From Straddle	T-stat	Average (Std. Dev.)	Decrease (%) From Straddle	T-stat
Profit ($)	0.92	1.53	0.61	0.56	1.21	0.28	0.28	0.79	-0.13	-0.13
Using B-A Mid.	(22.29)	(8.23)			(2.86)			(1.16)		
Call Leg	-2.02	-0.01			0.11			0.06		
Put Leg	2.91	1.54			1.10			0.73		
Profit ($)	-0.23	1.19	1.43	1.28	0.97	1.20	1.16	0.61	0.85	0.82
Using Bids	(22.25)	(9.30)			(2.72)			(1.05)		
Call Leg	-2.52	-0.14			0.04			0.02		
Put Leg	2.27	1.30			0.93			0.59		

	Straddle	**3% Strangle**	**5% Strangle**	**7% Strangle**
Number of Times:				
$\Delta = 1$	267	20	4	1
$\Delta = -1$	206	21	6	1
$\Delta = 0$	0	432	463	471
Total	473	473	473	473

Table 7: Greeks of Each Monthly Strategy at Initiation and Rollover.
This table contains average profits or losses using both Midpoints and Bids & Asks of short straddles and short strangles for the 109 months in the sample. Statistics for four strategies are presented: the at-the-money straddle, and three strangles, 3%, 5%, and 7% out-of-the-money, respectively. Values for Delta, Gamma, and Theta at initiation and rollover, as well as the changes between, are also presented.

		Straddle		**3% Strangle**		**5% Strangle**		**7% Strangle**	
Panel A: Average Profits or Losses Using Midpoints and Bids & Asks by Strategies and by Legs									
		Midpoint	Bid&Ask	Midpoint	Bid&Ask	Midpoint	Bid&Ask	Midpoint	Bid&Ask
Profit ($)	Average	8.71	5.10	8.80	6.64	8.09	6.52	6.50	5.17
	(Std. Dev.)	(27.51)	(27.58)	(20.51)	(20.75)	(14.51)	(14.67)	(9.72)	(9.86)
Short Call Leg		-5.58	-7.49	-1.24	-2.23	0.17	-0.44	0.36	-0.09
Short Put Leg		14.29	12.59	10.04	8.87	7.93	6.96	6.14	5.26
Panel B: Absolute Changes of Delta Exposures from Initiations to Rollovers by Strategies									
Delta	Average	0.5172		0.2717		0.0707		-0.0049	
	(Std. Dev.)	(0.2798)		(0.2649)		(0.2065)		(0.1457)	
Panel C: Average Greeks at Initiations and Rollovers by Strategies and by Legs									
		Initiation	Rollover	Initiation	Rollover	Initiation	Rollover	Initiation	Rollover
Delta	Average	0.0339	-0.1869	0.0776	-0.0887	0.1019	0.0045	0.0915	0.0296
	(Std. Dev.)	(0.0398)	(0.5982)	(0.0410)	(0.4246)	(0.0327)	(0.2645)	(0.0228)	(0.1647)
Short Call Leg		-0.4831	-0.5938	-0.2023	-0.2695	-0.0905	-0.1059	-0.0419	-0.0389
Short Put Leg		0.5169	0.4069	0.2798	0.1808	0.1924	0.1104	0.1333	0.0685
Gamma	Average	-0.0092	-0.0107	-0.0068	-0.0084	-0.0043	-0.0051	-0.0027	-0.0025
	(Std. Dev.)	(0.0024)	(0.0057)	(0.0016)	(0.0032)	(0.0014)	(0.0028)	(0.0010)	(0.0019)
Short Call Leg		-0.0046	-0.0053	-0.0036	-0.0055	-0.0020	-0.0032	-0.0011	-0.0013
Short Put Leg		-0.0046	-0.0053	-0.0032	-0.0029	-0.0023	-0.0018	-0.0016	-0.0012
Theta	Average	0.8440	1.0303	0.6833	0.8336	0.5234	0.6002	0.4065	0.4312
	(Std. Dev.)	(0.2674)	(0.4851)	(0.2616)	(0.3440)	(0.2347)	(0.3381)	(0.1933)	(0.3529)
Short Call Leg		0.4434	0.5374	0.2635	0.3590	0.1451	0.1980	0.0798	0.0973
Short Put Leg		0.4007	0.4929	0.4198	0.4746	0.3783	0.4021	0.3266	0.3340

Table 8: Monthly Percentage Returns from January 2020 through February 2021.
This table contains summary statistics of monthly percentage returns using the net margin approach from six option writing strategies for both the monthly and weekly trading schemes from January 2020 through February 2021. Panel A presents the mean, standard deviation, skewness, and excess kurtosis, as well as 1st percentile, 25th percentile, 50th percentile, 75th percentile, and 99th percentile of the monthly percentage returns from the monthly trading scheme. The results on the left-hand side are generated using the midpoints of the bid-ask spread, while the ones on the right-hand side use bid and ask prices to incorporate transaction costs. Panel B presents the same information for the monthly percentage returns from the weekly trading scheme.

Panel A. The Monthly Trading Scheme

	Using Midpoints of Bid-Ask Spread						Using Bids and Asks					
	ATM Short Straddle	Crash Neutral Short Straddle	Long Iron Butterfly	5% OTM Short Strangle	Crash Neutral Short Strangle	Long Iron Condor	ATM Short Straddle	Crash Neutral Short Straddle	Long Iron Butterfly	5% OTM Short Strangle	Crash Neutral Short Strangle	Long Iron Condor
Number of Months	14	14	14	14	14	14	14	14	14	14	14	14
Mean (%)	−5.14	−6.04	−3.58	−5.10	−6.20	−2.72	−6.07	−6.69	−4.12	−5.88	−6.60	−2.97
Standard Deviation (%)	21.60	15.32	11.33	26.77	17.52	10.13	22.11	15.48	11.47	27.38	17.69	10.30
Skewness	−1.10	−0.76	−0.99	−1.13	−1.17	−0.98	−1.12	−0.75	−1.00	−1.15	−1.15	−1.01
Excess Kurtosis	0.01	−0.86	0.52	−0.12	−0.11	−0.23	0.02	−0.88	0.51	−0.09	−0.16	−0.14
1 Percentiles (%)	−51.08	−31.44	−31.27	−61.31	−42.14	−25.44	−52.60	−32.46	−32.07	−63.72	−42.80	−26.35
25 Percentiles (%)	−19.86	−14.22	−9.85	−27.39	−13.57	−7.90	−21.38	−15.97	−10.04	−28.18	−14.53	−8.08
50 Percentiles (%)	0.98	−1.14	−1.22	5.75	1.27	1.02	0.45	−1.57	−1.59	5.35	0.98	0.82
75 Percentiles (%)	9.98	4.76	3.48	12.26	6.75	5.75	9.61	4.15	2.90	11.91	6.56	5.64
99 Percentiles (%)	17.27	10.63	9.87	21.24	7.76	6.13	16.24	10.27	9.55	20.64	7.32	6.03
Cum. Profit/Loss (%)	−68.91	−65.49	−45.62	−76.66	−68.92	−37.00	−73.85	−68.91	−49.91	−80.50	−70.97	−39.44

Panel B. The Weekly Trading Scheme (Weekly returns are multiplied into months to align with the months in Panel A.)

	Using Midpoints of Bid-Ask Spread						Using Bids					
	ATM Short Straddle	Crash Neutral Short Straddle	Long Iron Butterfly	5% OTM Short Strangle	Crash Neutral Short Strangle	Long Iron Condor	ATM Short Straddle	Crash Neutral Short Straddle	Long Iron Butterfly	5% OTM Short Strangle	Crash Neutral Short Strangle	Long Iron Condor
No. of Synthetic Months	14	14	14	14	14	14	14	14	14	14	14	14
Mean (%)	−9.29	−10.94	−9.90	−4.03	−6.85	−5.70	−10.25	−11.98	−11.02	−4.84	−7.75	−6.70
Standard Deviation (%)	24.65	24.61	24.81	22.92	22.89	20.85	24.85	24.97	25.20	23.22	23.53	21.67
Skewness	0.26	0.43	0.22	−1.42	−1.12	−1.17	0.27	0.38	0.16	−1.36	−1.14	−1.23
Excess Kurtosis	−0.33	−0.77	−0.77	0.82	−0.35	−0.06	−0.41	−0.81	−0.77	0.59	−0.36	0.10
1 Percentiles (%)	−55.06	−44.66	−46.66	−56.64	−52.79	−50.21	−55.67	−46.51	−50.69	−57.04	−53.84	−55.07
25 Percentiles (%)	−24.30	−26.97	−27.05	−12.19	−15.59	−15.80	−26.48	−27.78	−27.90	−13.23	−16.86	−17.19
50 Percentiles (%)	−16.64	−17.62	−10.21	2.98	2.04	2.01	−17.25	−18.31	−11.52	2.78	1.76	1.68
75 Percentiles (%)	9.36	8.56	8.52	10.13	7.21	7.13	8.74	7.87	7.80	9.71	6.62	6.46
99 Percentiles (%)	39.16	37.33	37.22	19.10	15.11	14.84	38.25	36.30	36.11	18.37	14.15	13.76
Cum. Profit/Loss (%)	−84.60	−87.95	−86.08	−66.45	−77.70	−70.60	−86.98	−90.11	−88.77	−70.76	−81.43	−76.09

Table 9: Returns from January 2020 through February 2021 for Three Strategies: Unhedged, Early Exit, and Dollar Recovery Hedge. This table contains monthly percentage returns using the net margin approach from the weekly trading scheme using the short strangle strategy, two other strategies, and the S&P 500 Index from January 2020 through February 2021. The bid and ask prices are used to incorporate transaction costs. The results in the Early Exit Strategy column stem from traders closing a losing position and holding cash for the rest of the week. The column called Hedged Weekly Short Strangle are the results of traders using the dollar loss recovery strategy wherein more options are sold to offset potential losses.

	Monthly Percentage Returns (Weekly Rebalancing)				Cumulative Dollar Profit from a $1,000-dollar Investment			
Month	S&P 500	(Unhedged) Weekly Short Strangle	Early Exit Strangle	Hedged Weekly Short Strangle	S&P 500	(Unhedged) Weekly Short Strangle	Early Exit Strangle	Hedged Weekly Short Strangle
December, 2019					2,646	10,868	10,868	10,868
January, 2020	2.87	2.38	2.38	2.38	2,721	11,127	11,127	11,127
February, 2020	−10.67	−57.04	−1.05	20.25	2,431	4,780	11,010	13,380
March, 2020	−16.28	−21.23	−71.03	−9.32	2,035	3,765	3,190	12,133
April, 2020	13.74	−50.89	−0.36	19.41	2,315	1,849	3,178	14,488
May, 2020	12.82	15.74	15.74	15.74	2,612	2,140	3,678	16,768
June, 2020	−2.00	18.37	18.37	16.30	2,560	2,533	4,354	19,502
July, 2020	7.07	6.82	6.82	6.82	2,741	2,706	4,651	20,832
August, 2020	2.26	2.69	2.69	2.69	2,803	2,779	4,776	21,393
September, 2020	−2.29	9.71	9.71	9.71	2,738	3,048	5,240	23,469
October, 2020	4.81	−13.23	−22.69	6.57	2,870	2,645	4,051	25,012
November, 2020	5.40	4.44	4.44	4.44	3,025	2,763	4,231	26,123
December, 2020	1.54	2.86	2.86	2.86	3,072	2,842	4,352	26,872
January, 2021	3.48	10.02	10.02	10.02	3,179	3,126	4,788	29,563
February, 2021	−1.95	1.65	1.65	1.65	3,117	3,178	4,867	30,051

Appendicies

A. Risk Measures and Covid-19 Crash Results

This appendix contains calculations for Value at Risk (VaR), Conditional Value at Risk (cVaR), Maximum Drawdown, and the Calmar Ratio for two strategies using the monthly returns under the monthly rebalancing scheme and the weekly rebalancing scheme for December 2010 through December 2019 sample period. These calculations are often used by traders to measure the risk of various portfolio positions and strategies.

Value at Risk measures the potential loss that the portfolios might experience over a given period of time. From our sample, the weekly rebalancing short strangle has the strongest results. In one month, the weekly rebalancing short strangle is expected to produce 0.37% or less returns at 5% chance, or suffer 13.6% or more losses at 1% chance.

Conditional Value at Risk quantifies the amount of tail risk a portfolio has. Still, the weekly rebalancing short strangle strategy has the lowest expected loss from our sample, -5.39% and -12.48% respectively, given 5% and 1% chance.

The Maximum Drawdown is the maximum observed loss from a peak to a bottom of a portfolio, before a new peak. The weekly rebalancing short strangle strategy has the lowest Maximum Drawdown, -13.6%, from 2010 to 2019.

The Calmar Ratio is a function of the portfolio's average annual rate of return versus its Maximum Drawdown. The higher the Calmar ratio, the better it performed on a risk-adjusted basis. Again, the weekly rebalancing short strangle strategy was the only one strategy has a Calmar ratio that is greater than 1. Specifically, its Calmar ratio is 2.22.

Table A1 contains these statistics for the Short Straddle and the 5% OTM Short Strangle for the monthly rebalancing and weekly rebalancing scheme. In general, we see that the statistics for the short strangle with weekly rebalancing present the most favorable statistics, save the annualized return, where the short strangle with monthly rebalancing dominates.

Table A2 contains the monthly returns for the two strategies by rebalancing scheme. The Short Strangle had higher return than the Short Straddle in eight of the fourteen months under the monthly rebalancing scheme, and in nine of fourteen months under the weekly rebalancing scheme. The highlighted cells are the months where the Covid-19 Crash mainly occurred.

Table A1: VaR, cVaR, Maximum Drawdown, and Calmar Ratio.
This table contains calculations for Value at Risk (VaR), Conditional Value at Risk (cVaR), Maximum Drawdown, and the Calmar Ratio for two strategies using the monthly rebalancing scheme and the weekly rebalacing scheme for the December 2010 through December 2019 sample period.

	Using Monthly Percentage Returns (%)			
	Monthly Rebalancing Short Straddle	Monthly Rebalancing Short Strangle	Weekly Rebalancing Short Straddle	Weekly Rebalancing Short Strangle
VaR(95%)	−18.02	−11.50	−32.26	0.37
VaR(99%)	−44.94	−48.47	−45.40	−13.60
cVaR(95%)	−26.93	−23.79	−35.12	−5.39
cVaR(99%)	−44.94	−48.47	−45.40	−13.60
Maximum Drawdown (%)	−50.11	−49.47	−87.39	−13.60
Annualized Return (%)	18.88	43.51	2.55	31.81
Calmar Ratio	0.37	0.87	0.02	2.22

Table A2: Monthly Returns From January 2020 through February 2021.
This table contains monthly returns for the short straddle and the 5% OTM short strangle strategies under the monthly rebalancing scheme and the weekly rebalancing scheme.

	Monthly Percentage Returns (%)			
	Monthly Rebalancing Short Straddle	Monthly Rebalancing Short Strangle	Weekly Rebalancing Short Straddle	Weekly Rebalancing Short Strangle
January, 2020	0.10	5.82	−15.94	2.38
February, 2020	−52.60	−57.11	−55.67	−57.04
March, 2020	−48.56	−63.72	−28.15	−21.23
April, 2020	−21.38	−28.74	−22.60	−50.89
May, 2020	−22.35	−28.18	−26.48	15.74
June, 2020	13.90	11.91	−22.08	18.37
July, 2020	−3.54	2.28	23.28	6.82
August, 2020	0.80	4.89	−3.95	2.69
September, 2020	16.24	16.82	38.25	9.71
October, 2020	12.76	20.64	−32.78	−13.23
November, 2020	−0.19	7.12	8.74	4.44
December, 2020	9.61	11.07	11.58	2.86
January, 2021	7.28	14.07	−18.57	10.02
February, 2021	2.98	0.75	0.90	1.65

B. Detailed Example of the Hedging Process

The Covid-19 Market Crash and quick rebound was a particularly harsh period over which to test the performance of pre-specified option writing trading strategies placed in a robotic way over the time period. Actual traders have many choices under these market conditions. These traders can act quickly during the trading day to modify their positions. With our data, we identified three strategies that a robotic trader can follow–assuming that closing prices reflect the opportunities for robotic traders.

As a detailed example of the hedging process, let's look at the first six dates of Table B1. On Friday's initiation, 2/21/2020, the premium received for the short strangle was \$1.00 (and only the put had a positive bid price). Thus, the trader receives \$100. The net margin per share is \$332.91, or $\$33,291$. There is no effect on the position as of the close on Monday, 2/22/2020.

On Tuesday, 2/25/2020, however, the S&P 500 index level of 3,128.21 renders the original put, with a strike of 3,170 in-the-money. Thus, the intrinsic value of this put option is \$41.79, but the implied loss of the short position is $-\$40.79$, because of the \$1.00 received at the initiation. If the trader exits early the loss for the week is \$60.85, because we assume the trader buys the options back at their ask price (which includes time value). Using the Dollar Loss Recovery Strategy, the trader would sell one at-the-money call option with a strike of 3,130 at the bid price of \$44.30. Thus, the portfolio value after this additional premium is received is $-\$40.79 + \$44.30$, which is \$3.51. The total margin for these three short options is \$800.35. Similarly, on Wednesday 2/26/2020, the 3,170 put moved \$11.82 more into the money. However because the trader had received an option premium of \$3.51 the previous day, the implied loss of the portfolio before hedging is $-\$8.31$, which signals another hedge. The trader sells an at-the-money with a strike of 3,120 for \$26.50, which yields an implied portfolio profit of \$18.19.

On Thursday, 2/27/2020, the 3,170 put option moved even more into the money, by \$137.63, yielding an implied loss of $-\$119.44$. If the trader sells 4 additional calls with a strike of 2,980 at \$30.80 each, the implied profit of the combined positions after these additional legs is $-\$119.44 + (4 \times \$30.80) = \$3.76$. The 3,170 put moved \$24.50 more into the money the next day, which yields a realized loss of $-\$20.78$ at expiration. Compared with the original weekly short strangle strategy, the unhedged trader's realized loss for the week was $-\$214.78$. Note that after the last hedges on Thursday, the total margin is $\$3,046.50$ per share, or $\$304,650$. The details for the other weeks are shown in the remaining rows of Table B1.

Table B1: Details of the Hedging Strategies, January 2020 through February 2021.
This table contains details of the calculations of the eight weeks when the early exit strategy and the dollar-loss recovery strategy were used from January 2020 through February 2021. We examined each week, but the Covid-19 stock market crash and rapid recovery between February and June 2020 had a big impact on a short strangle strategy. The first three columns include the date, the levels of the S&P 500 Index, and the daily percentage changes of the index. The next column reports the original position's implied or realized profit or loss using the weekly trading scheme for the short strangle strategy. When these European options were still alive, the profit/loss column contains the intrinsic value of the original position. When the option expires, the column contains the profit or loss of the original position. The next column reports the realized loss if traders close both short positions before the options expire. We use the (unreported) ask prices, which contain time value and intrinsic value. The next two column reports the implied/realized profit/loss of the hedged weekly short strangle strategy. We first report the portfolio value that reflects the original position's profit or loss, plus the value of any options added subsequently. We then report the result of adding a new leg to the original position for each trading day during the week. The next six columns contain the number of contracts, the strike prices, and the bid prices of the call and put options that are used to construct the original positions and any option legs added. The last column reports the net margin required by the exchange to initiate the original short positions, as well as the additional margin when additional options are added to the original short strangle position.

							Short Options Positions Taken						
Date	S&P 500 Index	S&P 500 Return (%)	Original Position Profit/ Loss ($)	Early Exit Loss ($)	Portfolio Value before Hedge ($)	Portfolio Value after Hedge ($)	Cks	Call Strike	Bid Price ($)	Cks	Put Strike	Bid Price ($)	Total Margin ($)
2/21/20	3,337.75		1.00		1.00		1	3,505	0.00	1	3,170	1.00	332.91
2/24/20	3,225.89	−3.35	1.00		1.00								332.91
2/25/20	3,128.21	−3.03	−40.79	**−60.85**	−40.79	3.51	1	3,130	44.30				800.35
2/26/20	3,116.39	−0.38	−52.61		−8.31	18.19	1	3,120	26.50				1,264.20
2/27/20	2,978.76	−4.42	−190.24		−119.44	3.76	4	2,980	30.80				3,046.50
2/28/20	2,954.22	−0.82	**−214.78**		**−20.78**								**3,046.50**
3/06/20	2,972.37		40.80		40.80		1	3,125	8.40	1	2,820	32.40	293.49
3/09/20	2,746.56	−7.60	−32.64	**−87.75**	−32.64	52.86	1	2,750	85.50				702.03
3/10/20	2,882.23	4.94	40.80		−5.93	66.87				1	2,880	72.80	1,132.13
3/11/20	2,741.38	−4.89	−37.82		−18.14	44.76	1	2,745	62.90				1,539.72
3/12/20	2,480.64	−9.51	−298.56		−476.72	59.28	8	2,485	67.00				4,481.61
3/13/20	2,711.02	9.29	**−68.18**		**−1,288.12**								**4,481.61**
3/13/20	2,711.02		78.20		78.20		1	2,850	20.70	1	2,575	57.50	270.63
3/16/20	2,386.13	−11.98	−110.67	**−129.55**	−110.67	20.13	1	2,390	130.80				624.68
3/17/20	2,529.19	6.00	32.39		24.00								624.68
3/18/20	2,398.10	−5.18	−98.70		24.00								624.68
3/19/20	2,409.39	0.47	−87.41		24.00								624.68
3/20/20*	2,437.98	1.19	**−58.82**		**24.00**								**624.68**
3/20/20	2,304.92	−4.34											

Table B1, Continued.

Date	S&P 500 Index	S&P 500 Return (%)	Original Position Profit/ Loss ($)	Early Exit Loss ($)	Portfolio Value before Hedge ($)	Portfolio Value after Hedge ($)	Short Options Positions Taken						Margin ($)
							Cks	Call Strike	Bid Price ($)	Cks	Put Strike	Bid Price ($)	
3/20/20	2,304.92		109.90		109.90		1	2,425	47.80	1	2,180	62.10	220.82
3/23/20	2,237.40	−2.93	109.90		109.90								220.82
3/24/20	2,447.33	9.38	87.57		87.57								220.82
3/25/20	2,475.56	1.15	59.34		59.34								220.82
3/26/20	2,630.07	6.24	−95.17	**−91.25**	−95.17	46.43				3	2,630	47.20	1,404.14
3/27/20	2,541.47	−3.37	**−6.57**		**−130.56**								**1,404.14**
4/03/20	2,488.65		28.10		28.10		1	2,615	9.20	1	2,360	18.90	244.65
4/06/20	2,663.68	7.03	−20.58	**−45.95**	−20.58	29.92				1	2,660	50.50	640.52
4/07/20	2,659.41	−0.16	−16.31		33.60								640.52
4/08/20	2,749.98	3.41	−106.88		−56.38	1.02				2	2,745	28.70	1,455.55
4/09/20	2,789.82	1.45	**−146.72**		**−38.82**								**1,455.55**
6/05/20	3,193.93		5.05		5.05		1	3,360	1.45	1	3,030	3.60	319.39
6/08/20	3,232.39	1.20	5.05		5.05								319.39
6/09/20	3,207.18	−0.78	5.05		5.05								319.39
6/10/20	3,190.14	−0.53	5.05		5.05								319.39
6/11/20	3,002.10	−5.89	−22.85	**−34.40**	−22.85	6.95	1	3,005	29.80				766.81
6/12/20	3,041.31	1.31	**5.05**		**−1.46**								**766.81**
10/23/20	3,465.39		3.35		3.35		1	3,640	0.35	1	3,290	3.00	344.42
10/26/20	3,400.97	−1.86	3.35		3.35								344.42
10/27/20	3,390.68	−0.30	3.35		3.35								344.42
10/28/20	3,271.03	−3.53	−15.62	**−39.40**	−15.62	21.68	1	3,275	37.30				831.10
10/29/20	3,310.11	1.19	3.35		5.54								831.10
10/30/20	3,269.96	−1.21	**−16.69**		**20.61**								**831.10**
10/30/20	3,269.96		35.30		35.30		1	3,435	9.10	1	3,105	26.20	325.53
11/02/20	3,310.24	1.23	35.30		35.30								325.53
11/03/20	3,369.16	1.78	35.30		35.30								325.53
11/04/20	3,443.44	2.20	26.86		26.86								325.53
11/05/20	3,510.45	1.95	−40.15	**−51.35**	−40.15	6.95				3	3,510	15.70	1,903.89
11/06/20	3,509.44	−0.03	**−39.14**		**6.28**								**1,903.89**

C. Calculating the Percentage Returns from Short Option Positions

C.1 The Zero-Sum Approach

A common method used in previous papers (Coval & Shumway, 2001; Goltz & Lai, 2009; Jha & Kalimipalli, 2010) is a zero-sum approach. In this approach, the researcher simply assigns a negative value to the percentage returns of a long position. By using the zero-sum approach, previous researchers implicitly assume the initial cost of a short position is also equal to the option premium. That is, the cost to calculate percentage returns using the zero-sum approach is:

$$\begin{aligned}\text{long percentage returns} &= \frac{\text{long dollar returns}}{\text{initial costs}} = \frac{c_{t+1} - c_t}{c_t} \\ \text{short percentage returns} &= -\text{long percentage returns} \\ &= -\frac{\text{long dollar returns}}{\text{initial costs}} = -\frac{c_{t+1} - c_t}{c_t} = \frac{c_t - c_{t+1}}{c_t}\end{aligned}$$

Thus, the percentage returns for our monthly and weekly trading schemes are:

$$R_{\text{short}}^{monthly} = -R_{\text{long}}^{monthly} = -\frac{(c_{t+1} - c_t) + (p_{t+1} - p_t)}{c_t + p_t} = \frac{(c_t - c_{t+1}) + (p_t - p_{t+1})}{c_t + p_t} \tag{3}$$

and

$$R_{\text{short}}^{weekly} = -R_{\text{long}}^{weekly} = \frac{[c_t - max(S_{t+1} - K_c, 0)] + [p_t - max(K_p - S_{t+1}, 0)]}{c_t + p_t}. \tag{4}$$

Although it has been used in previous literature, the zero-sum approach produces inaccurate results because it uses an incorrect initial cost. When shorting options, there is an additional cost—traders must post margin.

Appendix Table C1 contains the summary statistics for percentage returns using the zero-sum approach. We report results for all five strategies, using bid-ask midpoints as well as bids and asks. From Panel B, for example, the average monthly percentage return is 1,524% from the 5% OTM short strangle strategy for the weekly trading scheme. Moreover, the 25th, 50th, 75th, and 99th Percentiles of that strategy are 1,500%, 1,500%, 3,100%, and 3,100%, respectively. These results stem from the fact that, in most cases, a 5% out-of-the-money weekly option on the S&P 500 Index would expire worthless considering the fact that the weekly average percentage change of the S&P 500 Index is less than 5%. In this case, the long position trader loses 100% of the investment. But no one would claim that the corresponding short position trader has doubled his wealth, even if the percentage return from the zero-sum approach is 100%. In fact, the wealth of the short position trader only increases by the amount of option proceeds initially received.

C.2 The Net Margin Approach

To calculate an accurate percentage return, the real cost of the option writing strategy must be used. As shown by Santa-Clara and Saretto (2009), the number of options that a trader can sell is determined by the trader's capital and the exchange's margin requirements. To calculate a percentage return, we assume that the trader must post margin. Short option traders must deposit the margin requirement when they take their position.[23]

Independently of Murray (2013), we calculate the margin requirement of option writing strategies following the Chicago Board Options Exchange Margin Manual (2000). The manual states, "For the same underlying index with the same index multiplier, short put or short call requirement, whichever is greater, plus the option proceeds of the other side." Thus, the margin requirement for a short straddle or a short strangle is the maximum of the two possible margins, plus the option proceeds of the other side.[24]

Margin can be stated as,

$$\text{Margin} = \begin{cases} \max(\text{Margin}_{\text{call}}, \text{Margin}_{\text{put}}) + p_t & \text{if Margin}_{\text{call}} > \text{Margin}_{\text{put}} \\ & \text{or} \\ \max(\text{Margin}_{\text{call}}, \text{Margin}_{\text{put}}) + c_t & \text{if Margin}_{\text{call}} < \text{Margin}_{\text{put}} \end{cases} \tag{5}$$

For calls, the margin manual states the maximum of: "100% of option proceeds plus 15% of the underlying index value less the out-of-the-money amount, if any, or the call option proceeds plus 10% of the underlying index value." The margin formula for puts follows the margin formula for calls except that it incorporates 10% of the put's exercise price. That is,

$$\text{Margin}_{\text{call}} = \max(c_t + 15\% \times S_t - \max(K_c - S_t, 0), c_t + 10\% \times S_t), \tag{6}$$

$$\text{Margin}_{\text{put}} = \max(p_t + 15\% \times S_t - \max(S_t - K_p, 0), p_t + 10\% \times K_p), \tag{7}$$

For the insurance strategies, i.e., the "crash-neutral" short straddle and the long iron butterfly strategies, the margins of the strategies equal the margin of the short straddle plus the option premiums of the long out-of-the-money options.

[23] Kang, Kim, Kim, and Lee (2022) also document the influence of margin requirements on cash-constrained option writers.

[24] The margin requirements we use are the minimum CBOE requirement. Brokers are allowed to charge a higher margin, depending on the customer and on market conditions. For example, Santa-Clara and Saretto (2009) states that E-Trade requires that individual investors have margins sufficient against 40% market movement, instead of 15% as shown in Equations (6) and (7).

In the equations above, c_t and p_t are the prices of call and put options at the beginning of the holding period, K_c and K_p are the strike prices of call and put options, and S_t is the level of the S&P 500 Index at the beginning of the holding period.

The CBOE Margin Manual states (2000), "The proceeds from both short option sales may be applied to the initial margin requirement." Therefore, we compute Net Margin as

$$\text{Net Margin} = \text{Margin} - c_t - p_t. \tag{8}$$

The percentage returns of the short position equal the dollar returns divided by the net margin (or margin) requirement.

$$R^{monthly}_{\text{short}} = \frac{(c_t - c_{t+1}) + (p_t - p_{t+1})}{\text{Net Margin}(c_t, p_t, S_t, K_c, K_p)} \tag{9}$$

$$R^{weekly}_{\text{short}} = \frac{[c_t - max(S_{t+1} - K_c, 0)] + [p_t - max(K_p - S_{t+1}, 0)]}{\text{Net Margin}(c_t, p_t, S_t, K_c, K_p)} \tag{10}$$

We calculate the percentage returns using both the margin and the net margin requirement, but we report returns using the net margin requirement.[25]

From above, the net margin requirement is used as the initial cost to generate the percentage returns. The percentage returns that incorporate the cost of initiating the strategy are more useful for ordinary traders.

[25]For example, assume on December 20, 2019, a trader decided to short an at-the-money straddle on the S&P 500 Index Weekly Option Series expiring on December 27, 2019. To construct that short straddle, the trader needs to short 1 SPXW 3225 call at \$9.80 and 1 SPXW 3225 put at \$12.20. The underlying index closed at \$3221.22.

For simplicity, the margin calculation is shown for one share optioned, (i.e., not one contract for 100 shares). The call margin is \$9.80 + 15% × \$3,221.22 = \$489.203. The put margin is \$12.20 + 15% × \$3,221.22, = \$495.383. Because the call margin is smaller than the put margin, the margin requirement for this short straddle is the put margin plus the call option proceeds, which is \$495.383 + \$9.80, or \$505.183 per share optioned. For the position, the margin is \$505.183 × 100 = \$50,518.30.

The option proceeds are \$2,200 (\$9.80 + \$12.20) × 100. Following the CBOE Margin Manual, if the exchange allows the trader to use these proceeds as a deposit in the margin account, the option writer needs \$48,318.30, the net margin. Otherwise, the option writer must have \$50,518.30 in the margin account to short this straddle, even if the \$2,200 is received immediately. In this case, we would use the full margin requirement as the cost when calculating the percentage returns.

Table C1: Monthly Percentage Returns for the Zero-sum Approach.

This table contains summary statistics of the zero-sum approach monthly percentage returns from the five option writing strategies for both the monthly and the weekly trading schemes. Panel A presents the mean, standard deviation, skewness, and excess kurtosis, as well as 1st percentile, 25th percentile, 50th percentile, 75th percentile, and 99th percentile of the monthly trading scheme zero-sum monthly percentage returns. The results on the left-hand side are generated using the midpoints of the bid-ask spread, while the ones on the right-hand side use bid and ask prices to incorporate transaction costs. Panel B presents the same monthly return statistics for the weekly trading scheme.

Panel A. The Monthly Trading Scheme

	Using Midpoints of Bid-Ask Spread					Using Bids and Asks				
	ATM Short Straddle	5% OTM Short Strangle	5% ITM Short Guts	Crash Neutral Short Straddle	Long Iron Butterfly	Short Straddle	5% OTM Short Strangle	5% ITM Short Guts	Crash Neutral Short Straddle	Long Iron Butterfly
Number of Months	109	109	109	109	109	109	109	109	109	109
Mean (%)	11.40	46.29	3.60	6.90	6.55	6.33	38.08	0.32	2.39	2.42
Standard Deviation (%)	37.55	89.72	7.22	35.79	35.82	39.06	101.03	7.37	36.64	36.51
Skewness	−2.01	−4.11	−2.73	−1.48	−1.50	−2.07	−4.28	−2.86	−1.46	−1.48
Excess Kurtosis	5.57	18.23	13.49	2.94	3.04	6.01	19.94	13.89	2.91	2.99
1st Percentile (%)	−140.96	−403.25	−24.18	−111.61	−113.73	−150.28	−468.28	−26.82	−121.21	−121.33
25th Percentile (%)	−3.98	48.70	2.54	−11.69	−11.55	−7.59	41.27	−1.15	−14.76	−14.70
50th Percentile (%)	18.14	75.00	4.32	14.50	14.40	12.33	70.03	1.36	8.53	8.75
75th Percentile (%)	39.22	83.92	5.95	33.26	32.95	36.80	80.60	3.20	30.50	29.87
99th Percentile (%)	54.21	92.87	19.52	52.60	52.41	51.36	90.87	15.49	49.81	49.87

Panel B. The Weekly Trading Scheme (Weekly returns are multiplied into months to align with the months in Panel A.)

	Using Midpoints of Bid-Ask Spread					Using Bids				
	ATM Short Straddle	5% OTM Short Strangle	5% ITM Short Guts	Crash Neutral Short Straddle	Long Iron Butterfly	Short Straddle	5% OTM Short Strangle	5% ITM Short Guts	Crash Neutral Short Straddle	Long Iron Butterfly
No. of Synthetic Months	109	109	109	109	109	109	109	109	109	109
Mean (%)	29.88	1,524.31	2.70	24.63	23.98	7.65	1,460.53	−7.47	1.53	0.35
Standard Deviation (%)	289.52	2,704.19	4.75	288.17	288.03	279.27	3,017.05	5.84	277.20	276.94
Skewness	0.76	−5.78	4.25	0.70	0.69	0.61	−5.86	1.21	0.52	0.49
Excess Kurtosis	3.78	37.77	28.94	3.97	3.99	4.21	37.66	7.76	4.48	4.53
1st Percentile (%)	−837.67	−13,812.94	−4.97	−872.84	−878.24	−843.02	−16,728.96	−19.11	−879.90	−890.32
25th Percentile (%)	−101.50	1,500.00	0.92	−101.43	−101.57	−104.68	1,500.00	−10.42	−104.66	−104.76
50th Percentile (%)	−29.69	1,500.00	1.76	−36.36	−36.92	−47.85	1,500.00	−6.69	−57.60	−60.62
75th Percentile (%)	103.23	3,100.00	3.09	92.23	92.63	55.03	3,100.00	−5.04	44.03	41.40
99th Percentile (%)	999.34	3,100.00	21.91	986.98	984.65	949.57	3,100.00	9.08	932.35	927.47

D. Diagnostic Regressions for Short-Dated Straddles and Strangles

Theoretically, given an implied volatility level, short-dated at-the-money options should best capture the decay of options' time value assuming the price of the underlying Index does not change. The worst scenario for an option writing strategy would be to initiate the short position during a relatively low volatility level environment, and then the underlying price moves significantly. In this case, option writers have a relatively thin buffer to protect potential profits due to the relatively lower option premiums. To investigate why the weekly short-dated straddle under-performed the weekly short-dated strangle, we regress their dollar and percentage returns on the changes in the underlying index levels, the initial volatility levels, and their interaction terms.

Because both strategies symmetrically write paired call and put options, changes in underlying prices in either direction harm the option writers. As a result, we use the absolute value of the change and the absolute percentage change to measure how the underlying asset price deviates from its initial value.

For the initial volatility level, we use variables from both the market level and individual option level. Specifically, we use the standard VIX, the 9-day VIX, and the unweighted strategies' implied volatilities at the date the option writer initiates the positions. We also include interaction terms to capture different impacts of the changes in the underlying level in different volatility environments.

Panel A of Table D1 contains the regression results for the short straddle returns. The percentage change in the underlying prices has a significant negative impact, statistically and economically, on the performance of the short straddle strategy. The volatility level has a positive and significant impact on the return of the short straddle strategy, for all volatility measures. That is, a higher initial volatility environment, which inflates the option premiums, benefits the options writers by providing more buffer to any subsequent loss from changes in the underlying. Judging from the R-squared of the regression, the change of the underlying and the volatility level explain the majority of the variation within the returns of the short straddle strategy.

As for the short strangle strategy, the results differ markedly, as presented in Panel B of Table D1. Although the coefficient is negative and statistically significant, judging from the R-squared, the percentage change in underlying prices does not explain much of the variation in returns of the short strangle strategy. This finding makes sense considering the underlying prices need to move at least 5% in one direction within a week to impact the short strangle returns. The short strangle strategy exposes traders to relatively lower gamma exposures. Thus, writers sacrifice option premium inflow for "gamma insurance."

Although both the short straddle and the short strangle strategies start from an approximately delta-neutral position, the high gamma exposure in the short straddle strategy makes it more vulnerable to changes in the underlying price. The short strangle strategy is more robust to changes in the underlying price, until the change breaches a threshold level.

The initial level of implied volatility has a positive and significant impact on both strategies. With the short strangle strategy, there is a trade-off between the out-of-the-money options' moneyness and the potential profit from the strategy. That is, the higher the moneyness, the lower the profit. As such, perhaps an indicator based on market volatility could be used to design an option trading strategy. Traders could choose the short straddle strategy or the short strangle strategy with low moneyness options when the implied volatility measure is low. They could choose the short strangle strategy with high moneyness options when the implied volatility measure is high.

Table D1: Effects of VIX and Changes in the S&P 500 Index on the Returns for Short Straddles and Short Strangles This table presents regression coefficients with the dependent variable being the weekly returns from two option writing strategies between December 2010 and December 2019. The results in Panels A and B are from the short straddle and the short strangle, respectively. In columns (1) - (4), the dependent variable is the weekly dollar returns; in columns (5) - (8), the dependent variable is the percentage returns using the net margin approach. The independent variable, $\%\Delta$ in S&P 500, is the absolute percentage changes of the underlying S&P 500 index. $\%\Delta > 5\%$ is a binary variable, which equals zero if $\%\Delta$ in S&P 500 is less than 5%. VIX9D is the 9-day VIX at the date the option writer initiates the two short positions. We use this variables to measure the initial level of volatility from both the market and individual option perspectives. We also include the Position gamma, a variable that captures the initial jump risk exposures at initiation. Standard errors are in parentheses: *** p-value < 0.01, ** p-value < 0.05, * p-value < 0.10.

Panel A. The Short Straddle Strategy

Independent	Dependent Variable (DV): Dollar Returns				DV: Percentage Returns Using Net Margin			
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\%\Delta$ S&P 500	-14.52***	-19.62***	-17.39***	-19.76***	-4.783***	-6.563***	-5.760***	-6.598***
	(0.871)	(0.623)	(0.846)	(0.610)	(0.232)	(0.0661)	(0.214)	(0.0657)
$\%\Delta > 5\%$	5.091	5.257	9.489	5.864	-0.643	-0.634	0.855	-0.481
	(14.64)	(9.918)	(14.99)	(10.32)	(2.583)	(0.718)	(2.504)	(0.745)
VIX 9 Day		2.064***		1.958***		0.726***		0.699***
		(0.130)		(0.163)		(0.0129)		(0.0162)
Position Gamma			866.4***	122.5*			295.0***	30.87***
			(61.79)	(62.93)			(21.91)	(8.816)
Constant	20.79***	-3.496**	47.33***	1.491	7.078***	-1.495***	16.11***	-0.238
	(0.949)	(1.414)	(2.144)	(3.527)	(0.292)	(0.168)	(0.779)	(0.415)
Observations	473	468	473	468	473	468	473	468
R-squared	0.633	0.882	0.733	0.883	0.682	0.970	0.791	0.971

Panel B. The Short Strangle Strategy

Independent	Dependent Variable (DV): Dollar Returns				DV: Percentage Returns Using Net Margin			
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\%\Delta$ S&P 500	0.574***	-0.235**	0.212*	-0.296***	0.331***	-0.209***	0.0448	-0.215***
	(0.148)	(0.0945)	(0.116)	(0.0937)	(0.123)	(0.0770)	(0.0819)	(0.0804)
$\%\Delta > 5\%$	-12.39***	-12.38***	-13.36***	-11.74***	-7.674***	-7.670***	-8.441***	-7.615***
	(3.607)	(3.254) (	3.505)	(3.245)	(2.522)	(2.390)	(2.543)	(2.374)
VIX 9 Day		0.329***		0.455***		0.220***		0.231***
		(0.0294)		(0.0405)		(0.0267)		(0.0281)
Position Gamma			980.7***	666.9***			-776.3***	56.90
			(165.2)	(185.4)			(140.0)	(125.5)
Constant	0.677***	-3.192***	-0.868***	-3.650***	0.371***	-2.222***	-0.852***	-2.261***
	(0.162)	(0.371)	(0.311)	(0.343)	(0.135)	(0.352)	(0.273)	(0.321)
Observations	473	468	473	468	473	468	473	468
R-squared	0.279	0.661	0.458	0.686	0.234	0.603	0.476	0.603