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Option strategies: Good deals and margin calls

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Abstract

We provide evidence that trading frictions have an economically important impact on the execution and the profitability of option strategies that involve writing out-of-the-money put options. Margin requirements, in particular, limit the notional amount of capital that can be invested in the strategies and force investors to close down positions and realize losses. The economic effect of frictions is stronger when the investor seeks to write options more aggressively. Although margins are effective in reducing counterparty default risk, they also impose a friction that limits investors from supplying liquidity to the option market.

JEL classification: G12; G13; G14

Keywords: Limits to arbitrage; Option strategies

> Dear Customers,
>
> As you no doubt are aware, the New York stock market dropped precipitously on Monday, October 27, 1997. That drop followed large declines on two previous days. This precipitous decline caused substantial losses in the funds' positions, particularly the positions in puts on the Standard & Poor's 500 Index. [...] The cumulation of these adverse developments led to the situation where, at the close of business on Monday, the funds were unable to meet minimum capital requirements for the maintenance of their margin accounts. [...] We have been working with our broker-dealers since Monday evening to try to meet the funds' obligations in an orderly

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> fashion. However, right now the indications are that the entire equity positions in the funds has been wiped out.
> Sadly, it would appear that if it had been possible to delay liquidating most of the funds' accounts for one more day, a liquidation could have been avoided. Nevertheless, we cannot deal with "would have been." We took risks. We were successful for a long time. This time we did not succeed, and I regret to say that all of us have suffered some very large losses.
> — Letter from Victor Niederhoffer to investors in his hedge funds.

Jackwerth (2000), Coval and Shumway (2001), Bakshi and Kapadia (2003), Bondarenko (2003), Jones (2006), and Driessen and Maenhout (2007) find that strategies that involve writing put options on the S&P 500 index offer very high Sharpe ratios ("good deals")—close to two on an annual basis for writing straddles and strangles.[2] In the finance literature the debate over the relevance of those results in determining whether out-of-the-money (OTM) put options are or are not mis-priced is quite fervid. On one hand, the strategies' returns are difficult to justify as remuneration for risk in the context of models with a representative investor and standard utility function.[3] Even fairly general semi-parametric approaches such as those followed by Bondarenko (2003) and Jones (2006) or non-standard utility functions, such as in Driessen and Maenhout (2007), have little success in explaining the high returns. On the other hand, Benzoni et al. (2005) study an economy where very low mean reversion in the state variable leads investors to keep buying options for insurance purposes long after a market crash has occurred, therefore keeping high prices of put options. Bates (2007) propose to evaluate the historical option returns relative to those produced in simulation by commonly used option pricing models. They find no evidence of mis-pricing when using a stochastic volatility model with jumps.

A third stream of the literature investigates the impact of demand pressure on option prices. Bollen and Whaley (2004) show that net buying pressure is positively related to changes in the implied volatility surface of index options. Garleanu et al. (2005) argue that the net demand of private investors affects the way market-makers price options. In their model, high prices are driven by market makers who charge a premium as compensation for the fact that they cannot completely hedge an unbalanced inventory. In summary, Garleanu et al. argue that demand pressure causes option prices to be higher than they would otherwise be in the presence of a more widespread group of liquidity providers. Indeed, prices are so high that trading strategies that involve providing liquidity to the market (such as writing options) appear to earn an exceptionally high returns.

On one hand if put options are mis-priced, perhaps because their prices are bid up by demand pressure, the question of why such trading opportunities have not attracted the attention of sophisticated investors, who do not need to be completely hedged, is still un-answered and therefore deserves attention. On the other hand, if put options are not

[2]Similarly, Day and Lewis (1992), Christensen and Prabhala (1998), Jackwerth and Rubistein (1996), and Rosenberg and Engle (2002) find discrepancies between the empirical and the implicit distribution of the S&P 500 returns.

[3]A large set of studies concludes that option prices can be rationalized only by very large volatility and/or jump risk premia. See, for example, Bates (1996), Bakshi et al. (1997), Bates (2000), Chernov and Ghysels (2000), Buraschi and Jackwerth (2001), Benzoni (2002), Pan (2002), Chernov et al. (2003), Eraker et al. (2003), Jones (2003), Eraker (2004), Liu et al. (2005), Santa-Clara and Yan (2004), Benzoni et al. (2005), Xin and Tauchen (2005), and Broadie et al. (2006). Bates (2001) introduces heterogeneous preferences while Buraschi and Alexei (2006) consider heterogeneous beliefs.

mis-priced and the high put option returns are due to very large premia for volatility and/or jump risk, a question still remains as to the ability of investors participating in the market. We do not attempt to distinguish between those two alternatives, but simply try to measure the impact of margins on the realized return of option trading strategies. In the broad sense, our paper therefore is focused on developing and testing the hypothesis that margin requirements, although effective in reducing counterparty default risk, impose a friction that might significantly blunt the effectiveness of option markets for risk sharing among investors.

Margin requirements limit the notional amount of capital that can be invested in the strategies and force investors out of trades at the worst possible times (precisely when they are losing the most money). Our evidence indicates that, once margins are taken into account, the profitability and the risk-return trade off of the "good deals" is not as economically significant as previously documented. Therefore, we argue that these frictions make it difficult for investors (non-market-makers) to systematically write options.

Our study analyzes data on S&P 500 options from January of 1985 to April of 2006, a period that encompasses a variety of market conditions. We study the effect of two different margining systems: the system applied by the Chicago Board of Options Exchange (CBOE) to generic customer accounts, and the system applied by the Chicago Mercantile Exchange (CME) to members' proprietary accounts and large institutional investors. We find that the requirements imposed by the CBOE are more onerous and difficult to maintain than the requirements imposed by the CME. In both cases, margins affect the execution and the profitability of option strategies. In particular, margins influence the strategies along two dimensions: they limit the number of contracts that an investor can write, and they force the investor to close down positions. For example, a CBOE customer with an availability of capital equivalent to one S&P 500 futures contract could write only one ATM near-maturity put contract if she wanted to meet the maximum margin call in the sample. If the investor chose to write more contracts, she would not be able to always meet the minimum requirements. As a consequence, her option positions would have to be closed. Forced liquidations happen precisely when the strategies are losing the most money, or in other words when the market is sharply moving against the investor's positions— a sudden decrease of the underlying value or an increase in market volatility. Therefore the investor is forced to realize losses. Partial and total liquidations due to margin calls also force the investor to execute a larger number of trades, increasing the importance of transaction costs.

We test for the statistical relationship between the portfolio exposure to options and measures that proxy for the execution and the profitability of the strategies. The results of this analysis are supportive of our conjecture: increasing the portfolio exposure to the option and controlling for the level of coverage leads to a deterioration of the portfolio profitability and to a bigger difference between the effective and the target weight. We observe this positive relationship when we consider the Sharpe ratio, the Leland (1999) alpha, and the manipulation-proof performance measure (MPPM) of Ingersoll et al. (2007).

In synthesis, the main result of this paper is that the difference between option "margined" realized returns and option "un-margined" returns can be quite substantial when investors are subject to margins and do not have unlimited access to capital when the market is in a downturn state. Consequently, our paper contributes to the literature that studies the impact of demand pressure on option prices by showing how frictions limit arbitrageurs from supplying liquidity to the market and hence releasing pressure on market-makers. In that sense, this study complements the results of Garleanu et al. (2005). Moreover, our results help explain the findings of Jones (2006). Jones considers returns before margins are taken into account and finds that only a portion of the returns can be explained by jump and volatility factors. We show that part of these "un-margined" returns are not available to investors and therefore should not be explainable in terms of remuneration for risk. Our paper also contributes to the vast literature that studies trading costs in option markets (see, for example, Constantinides et al., 2008) by offering evidence on the effect of a particular source of friction, which has not been explicitly considered: margin requirements.[4]

Consistent with the arguments of Shleifer and Vishny (1997), Duffie et al. (2002), and Liu and Longstaff (2004) about the limits to arbitrage, our findings could help explain why the good deals in options prices might be difficult to arbitrage away and why speculative investors do not compete with market-makers to provide liquidity by taking the short side of the trade in index options. The literature on limits to arbitrage has not reached complete consensus. While Battalio and Stultz (2006) find no evidence in favor of the limits to arbitrage argument, Ofek et al. (2004), Duarte et al. (2006), and Han (2008) find that relative mis-pricings are stronger when there are more impediments to arbitrage activity. Our paper adds to the above studies in providing further empirical evidence in favor of the limits to arbitrage argument.

Under the opposite view that put option prices are perfectly consistent with large risk premia for volatility and/or jump risk, our results are still interesting in that they document how options might not be effective instruments for risk sharing among investors.

The rest of the paper is organized as follows. In Section 1 we describe the data. We explain the option strategies studied in the paper and give summary statistics of the strategy returns in Section 2. Section 3 describes the margin requirements analyzed in this paper. In Section 4, we analyze the impact of margin requirements on the execution and the profitability of the strategies in the case where the investor is allowed to trade in options and the risk-free rate. We extend the investment opportunity set to include index futures in Section 5. Section 6 concludes.

1. Data

All our main tests are conducted using data provided by the Institute for Financial Markets for American options on S&P 500 futures traded at the CME. This dataset includes daily closing prices for options and futures traded between January 1985 and May 2001. We use data from OptionMetrics for European options on the S&P 500 index, which are traded at the CBOE to estimate bid–ask spreads for various levels of moneyness. This dataset includes daily closing bid and ask quotes for the period between January 1996 and April 2006.

[4]Few studies consider margin requirements in options: Heath and Jarrow (1987) show that the Black–Scholes model still holds. Mayhew et al. (1995) and John et al. (2003) study the implication of margins for liquidity and the speed at which information is incorporated into prices. Driessen and Maenhout (2007) and Driessen et al. (2008) incorporate margins in portfolio optimization exercises. There is also a vast literature that studies trading costs in the context of option markets. Some examples are Leland (1985), Figlewski (1989), Bensaid et al. (1992), Green and Figlewski (1999), Constantinides and Zariphopoulou (2001), Constantinides and Perrakis (2002), and Constantinides et al. (2008).

To minimize the impact of recording errors and to guarantee homogeneity in the data, we apply a series of filters. First, we eliminate prices that violate basic arbitrage bounds. Second, we eliminate all observations for which the bid is equal to zero, or for which the spread is lower than the minimum ticksize (equal to $0.05 for options trading below $3 and $0.10 in any other cases). Finally, we exclude all observations for which the implied Black (1976) volatility is larger than 200% or lower than 1%.

We construct the option return from the closing of the first trading day of each month to the closing price of the first trading day of the next month. We obtain a time-series by computing the option return in each month of the sample. The returns of the strategies are not affected by the American nature of the options traded in the CME. We compute returns based on the prices published by the exchange that already include the early exercise premium assessed by the market participants. The results we obtain with the European options traded in the CBOE are very similar to the results obtained with the American options traded on the CME.

2. Option strategies

We analyze several option strategies standardized at different moneyness levels. We focus on one maturity, corresponding to approximately 45 days, and three different levels of moneyness, at-the-money (ATM), 5%, and 10% OTM. All the strategies are constructed so that they involve writing options.

We consider only strategies that involve at least one put contract since those strategies have been found to generate large returns—see, for example, Coval and Shumway (2001), Bakshi and Kapadia (2003), Bondarenko (2003), Jones (2006), and Driessen and Maenhout (2007). We consider naked and covered positions in put options, delta-hedged puts, and combinations of calls and puts, such as straddles and strangles.[5] A naked position is formed simply by writing the option contract. A covered put combines a negative position in the option and a short in the underlying. A delta-hedged put is formed by selling one put contract, as well as delta shares of the underlying. We also study strategies that involve combinations of calls and puts, such as straddles and strangles. A straddle involves writing a call and a put option with the same strike and expiration date. A strangle differs from a straddle in that the strike prices are different: write a put with a low strike and a call with a high strike.

2.1. Summary statistics

We start by discussing the characteristics of the options used in constructing the monthly returns. In Table 1, for any moneyness level, we tabulate the average Black and Scholes implied volatility and the average price as a percentage of the value of the underlying. This last information is essential to understand the magnitude of the portfolio weights that we will analyze in the following sections and gives us an idea of how expensive the options are relative to the underlying value. We report results for the S&P 500 futures options (CME sample) in Panel A and results for the S&P 500 index options (CBOE sample) in Panel B.

[5]In a previous version of this paper, we used to study a much wider set of option strategies. Although the result about these strategies are still interesting, we do not report them for the sake of brevity. These results are available from the authors upon request.

Table 1
Descriptive statistics of option data.

	Put			Call		
	10%	5%	ATM	ATM	5%	10%
Panel A: CME sample 1985–2001						
IV	0.254	0.224	0.192	0.186	0.173	0.161
Price/S	0.006	0.013	0.028	0.027	0.009	0.002
Panel B: CBOE sample 1996–2006						
IV	0.264	0.229	0.198	0.196	0.175	0.169
Price/S	0.006	0.013	0.027	0.028	0.009	0.002

In this table we report the average Black and Scholes implied volatility (IV) as well as the average ratio of the option price to the value of the underlying index (price/S) for calls and puts on the S&P 500 futures. We focus on one maturity, corresponding to approximately 45 days to maturity. We report statistics for option at the money (ATM), and out-of-the-money by 5% and 10%. Option and S&P 500 future closing prices were sampled daily between January 1985 and May 2001. The data are provided by the Chicago Mercantile Exchange through the Institute for Financial Markets (all options are American). Options and S&P 500 index closing prices were sampled daily between January 1996 and April 2006. The data are provided by Optionmetrics (all options are European).

Table 2
Returns of option strategies.

	Mean	Std	Min.	Max.	Skew.	Kurt.	SR	LEL
Put ATM	−0.296	0.861	−0.990	5.249	2.680	13.049	−0.344	−0.152
Put 5% OTM	−0.456	1.060	−0.991	10.004	5.923	51.711	−0.430	−0.293
Put 10% OTM	−0.509	1.663	−0.990	20.628	10.880	136.358	−0.306	−0.308
Cov Put ATM	−0.004	0.024	−0.073	0.095	0.818	4.772	−0.135	−0.003
Cov Put 5% OTM	−0.002	0.033	−0.098	0.108	0.228	3.324	−0.033	−0.003
Cov Put 10% OTM	−0.000	0.038	−0.113	0.115	−0.130	3.406	−0.003	−0.003
Delta Put ATM	−0.011	0.029	−0.063	0.233	3.894	29.712	−0.376	−0.001
Delta Put 5% OTM	−0.018	0.047	−0.092	0.469	6.557	64.081	−0.377	0.007
Delta Put 10% OTM	−0.020	0.085	−0.130	1.084	11.261	145.891	−0.236	0.012
Straddle ATM	−0.117	0.474	−0.970	2.845	2.531	12.571	−0.247	−0.088
Strangle 5% OTM	−0.338	0.760	−1.007	3.942	3.101	14.253	−0.445	−0.305
Strangle 10% OTM	−0.510	0.779	−1.007	5.676	4.484	29.156	−0.654	−0.496

This table reports summary statistics of the strategy returns: average, standard deviation, minimum, maximum, skewness, kurtosis, Sharpe ratio (SR), and Leland's alpha (LEL). The returns are computed as the return to a strategy that writes the options. Options and S&P 500 futures closing prices were sampled daily between January 1985 and May 2001. The data are provided by the Chicago Mercantile Exchange through the Institute for Financial Markets. All options are American. For comparison, the S&P 500 index has a mean return of 1.3%, a standard deviation of 4.3%, skewness of −0.804, Sharpe ratio of 0.189, and Leland's alpha of 0.

The average ATM implied volatility is around 19% in the 1985–2001 sample and around 20% in the 1996–2006 sample. In general, downside protection (OTM puts) is more expensive than upside leverage (OTM calls).

Table 2 reports the average, standard deviation, minimum, maximum, skewness, kurtosis, Sharpe ratio, and Leland (1999) alpha of the monthly returns of the strategies discussed in the previous section.[6] As a first attempt, to understand the statistical properties of the strategies, we compute the return of a long position in the option, which is financed by borrowing at the risk-free rate.

Table 2 is divided into four panels that group strategies with similar characteristics. The average returns of all the strategies are negative across all moneyness levels. Selling 10% OTM put contracts earns 51% per month on average, with a Sharpe ratio of 0.306, and a Leland alpha of 30% (first panel of Table 2). The reward is accompanied by considerable risk: the strategy has a negative skewness of –10.880, caused by a maximum possible loss of 20 times the notional capital of the strategy. These numbers are comparable to those reported by Bondarenko (2003). Protective put strategies also have negative returns; however, the Sharpe ratios are very small. Similarly to Bakshi and Kapadia (2003), we find that the delta-hedged returns are all associated with large Sharpe ratios (e.g., the 10% OTM delta-hedged put has an average return of −2.0% per month with a Sharpe ration of −0.236). The Leland alpha, however, is positive at 1.2%, indicating that, according to that performance measure, writing delta-hedge puts would not be a good investment. Straddles and strangles offer high average returns, Sharpe ratios, and Leland alphas, which are increasing with the level of moneyness: a short position in the ATM straddle returns on average 11% per month, with a Sharpe ratio of 0.247 and a Leland alpha of 8.8%, while a short position in the 10% OTM strangle earns an average 51% per month, with a Sharpe ratio of 0.654 and a Leland alpha of 49%. These numbers are comparable to those reported by Coval and Shumway (2001).

Similar statistics for the European S&P 500 index options, over the period 1996–2006, can be found in the first three columns of Table 4. In that sample, the average strategy returns are very close to the average returns in the 1985–2001 sample. However, the strategy volatilities are lower in the 1996–2006 sample, thus leading to higher Sharpe ratios.

Although the general performance of the strategies is consistent in various sub-samples, the inclusion of the October 1987 crash does change the magnitude of the profitability of some strategies. For this reason, we prefer to leave the pre-crash observations in the sample despite the evidence that a structural break did occur in those years (for example, Jackwerth and Rubistein, 1996; Benzoni et al., 2005), and the fact that the maturity structure of the available contracts changed after the crash (for example, Bondarenko, 2003). Complete summary statistics for the various sub-samples are not reported in the paper. A brief discussion follows. Let us consider, for example, the 5% OTM put. The average return for the years around the 1987 market crash, January 1985 to December 1988, is −25.2%, while in the rest of the sample, January 1989 to May 2001, the strategy averages −52.1%. Even if we consider the more recent period that starts with the burst of the "Internet bubble," 2001 up to 2006, the return of the S&P 500 index put still averaged −30% per month in a substantially bearish market.

[6]Leland (1999) provides a simple correction of the CAPM, which allows the computation of a robust risk measure for assets with arbitrary return distributions. This measure is based on the model proposed by Rubinstein (1976) in which a CRRA investor holds the market in equilibrium. The discount factor for this economy is the marginal utility of the investor and expected returns have a linear representation in the beta derived by Leland. Subtracting Leland's beta times the market excess return from the strategy returns gives an estimate of the strategy alpha. Results for the alpha derived from CAPM and the Fama and French (1993) three factor model are very similar and are available from the authors upon request.

2.2. Statistical significance

Inference on the statistics reported in Table 2 is particularly difficult since the distribution of option returns is far from normal, and characterized by heavy tails and considerable skewness. For this reason, the usual asymptotic standard errors are not suitable for inference. Instead, we base our tests on the empirical distribution of returns obtained from 1000 non-parametric bootstrap repetitions of our sample. Each repetition is obtained by drawing with replacement the returns of the strategies. We construct and report the 95% confidence interval or the p-value under the null hypothesis. An exact description of the bootstrap procedure can be found in Davison and Hinkley (1997).

In Table 3, we present 95% confidence intervals for the mean, Sharpe ratio, and Leland alpha of the different strategies. We note that 9 out of 12 strategies have mean returns, Sharpe ratio and Leland alphas are statistically different from zero at the 5% level. None of the covered puts has statistically significant means or Sharpe ratios or Lelans's alphas. Four strategies have Sharpe ratios that are statistically higher than the market's Sharpe ratio at the 95% confidence level: the 5% OTM put, the ATM Delta-Hedge Put, and the 5% and 10% OTM strangles. In general, however, Sharpe ratios and Leland alphas are really large, especially for strategies that are not very correlated with the market.

2.3. Transaction costs

Trading options can be quite expensive, not only because of the high commissions charged by brokers, but, most importantly, because of the large bid–ask spreads at which options are quoted. We investigate the magnitude of bid–ask spreads, as well as their

Table 3
Bootstrapped confidence intervals.

	Mean (95%)		SR (95%)		LEL (95%)	
Put ATM	−0.404	−0.176	−0.605	−0.175	−0.407	−0.164
Put 5% OTM	−0.583	−0.304	−0.948	−0.204	−0.593	−0.293
Put 10% OTM	−0.682	−0.249	−1.332	−0.092	−0.699	−0.241
Cov Put ATM	−0.006	0.000	−0.296	0.002	−0.002	0.005
Cov Put 5% OTM	−0.006	0.003	−0.177	0.101	−0.003	0.004
Cov Put 10% OTM	−0.005	0.005	−0.142	0.135	−0.006	0.009
Delta Put ATM	−0.015	−0.007	−0.705	−0.189	−0.009	−0.003
Delta Put 5% OTM	−0.023	−0.011	−0.916	−0.157	−0.012	−0.003
Delta Put 10% OTM	−0.029	−0.007	−1.066	−0.051	−0.014	−0.003
Straddle ATM	−0.188	−0.057	−0.493	−0.104	−0.183	−0.051
Strangle 5% OTM	−0.446	−0.242	−0.810	−0.268	−0.442	−0.234
Strangle 10% OTM	−0.614	−0.399	−1.294	−0.388	−0.617	−0.402

This table reports 95% bootstrap confidence intervals for three of the summary statistics reported in Table 2: average return, Sharpe ratio, and Leland's alpha. The empirical distribution of returns is obtained from 1000 non-parametric bootstrap repetitions of our sample. Each repetition is obtained by drawing with replacement the returns of the strategies. Options and S&P 500 futures closing prices were sampled daily between January 1985 and May 2001. The data are provided by the Chicago Mercantile Exchange through the Institute for Financial Markets. All options are American.

Table 4
Impact of transaction costs on option strategies' returns.

	Mid-price			Bid-to-ask		
	Mean	SR	LEL	Mean	SR	LEL
Put ATM	0.251	0.307	0.186	0.197	0.229	0.129
Put 5% OTM	0.463	0.599	0.406	0.401	0.486	0.340
Put 10% OTM	0.612	1.054	0.572	0.521	0.801	0.476
Delta Put ATM	0.011	0.673	0.011	0.008	0.508	0.008
Delta Put 5% OTM	0.017	0.748	0.018	0.014	0.600	0.014
Delta Put 10% OTM	0.023	0.907	0.025	0.018	0.714	0.020
Straddle ATM	0.181	0.666	0.187	0.128	0.460	0.135
Strangle 5% OTM	0.352	0.673	0.350	0.276	0.497	0.274
Strangle 10% OTM	0.519	0.972	0.510	0.400	0.666	0.388

In this table we analyze the impact of the bid-ask spread on the strategies' returns. For each strategy, we report the mean return, the Sharpe ratio, and the Leland alpha under two scenarios: trades executed at mid-point prices (left part of the table) and trades executed at the bid price when options are written and at the ask price when options are bought (right part of the table). Options and S&P 500 index closing prices were sampled daily between January 1996 and April 2006. The data are provided by Optionmetrics. All options are European.

impact on strategy returns by analyzing the S&P 500 index option OptionMetrics database, which provides the best closing bid and ask prices of every trading day. This database covers a shorter and more recent period (January 1996 to April 2006) than the futures option database that was used in the previous section. Therefore, the trading costs that we estimate are, if anything, lower than those prevailing in the first part of the longer sample.

In Table 4, we compare average, Sharpe ratio, and Leland alpha of the strategy returns obtained with and without accounting for transaction costs. We compute the relevant return for an investor writing options from mid-price to mid-price (left part of the table) and from bid to ask price (right part of the table).

The comparison of the statistics in the two scenarios confirms the findings of George and Longstaff (1993). Average returns from writing puts are 5%–9% per month lower when transaction costs are considered.[7] The return difference is larger for OTM options than it is for ATM options. The impact of trading costs on the return of straddles and strangles is similar. For example, the bid-ask spread accounts for a loss of 5.3% for the ATM straddle. The impact on delta-hedged strategies is lower in absolute terms but it is approximately of the same proportional magnitude. Transaction costs decrease Sharpe ratios by even larger proportions, due to the fact that the strategy volatility is also affected. The impact of transaction costs on Leland alphas is very similar in magnitude to the impact on average returns.

As we were expecting given the extensive literature on the topic (see, for example, Constantinides et al., 2008) transaction costs do not completely eliminate the profitability of the option strategies. The impact is, however, economically important, making the inclusion of round-trip costs essential for the rest of our analysis.

[7]If the investor holds the options to maturity, only half of the cost is incurred.

The evidence presented in this section, which essentially confirms the findings already reported in the vast existing literature, establishes that several strategies involving writing options have produced large average returns (even after transaction costs). Many attempts to directly or indirectly explain this empirical regularity have been proposed: remuneration for volatility and jump risk, demand pressure, non-standard preferences, and market segmentation (see Bates, 2003 for a review). All these factors have an impact on how options are priced and might, therefore, be responsible for the "high" put prices that generate the profitability of the option strategies. It is not clear however what portion of these profits is attributable to remuneration for risk (see, for example, Jones, 2006).

We conjecture that returns to option trading strategies are affected by market frictions, creating a wedge between the returns that are observable and those that are realizable. In the following sections, we investigate the feasibility of these option strategies, focusing in particular on how margin requirements impact the returns of the strategies.

3. Margin requirements

All the strategies studied in this paper involve a short position in one or more put contracts. When an investor writes an option, the broker requests a deposit in a margin account of cash or cash-equivalent instruments such as T-bills. The amount requested corresponds to the initial margin requirement. The initial margin is the minimum requirement for the time during which that position remains open. Every day a maintenance margin is also calculated. A margin call originates only if the maintenance margin is higher than the initial margin. If the investor is unable to provide the funds to cover the margin call, the option position is closed and the account is liquidated.

Minimum margin requirements are determined by the option exchanges under supervision of the Security Exchange Commission (SEC) and the Commodity Futures Trading Commission (CFTC). Margin keeping is maintained by members of clearing houses.[8]

There are essentially three types of account that are maintained by members of a clearing house: market-maker accounts, proprietary accounts, and customer accounts. The difference among these accounts is that market-maker accounts are margined on their net positions (short positions can be offset by long positions) while other accounts are margined on all the existing short positions. In this paper, we study the customer minimum margin requirements imposed by the CBOE, and the proprietary (speculative) account margins imposed by the CME to its members. The margin requirements that are applied by the two clearing houses to members are very similar in their spirit. The CME has a system called Standard Portfolio Analysis of Risk (SPAN), while the OCC has a system called Theoretical Intermarket Margin System (TIMS). Both systems are based on scenario analysis, and in what follows we assume them to be interchangeable.[9] Moreover, some

[8]In the United States there are 11 Derivatives Clearing Organizations registered with the CFTC. Of these, the CME clears trades on futures and futures options traded at the CME, while the Options Clearing Corporation (OCC) clears trades on the stock and index options traded at the American Stock Exchange, the Boston Options Exchange, the CBOE, the International Securities Exchange, the Pacific Stock Exchange, and the Philadelphia Stock Exchange.

[9]The OCC does not have any available technical documentation that could be used to reconstruct the exact functioning of the TIMS system. However, conversation with OCC personnel confirmed that the system is similar to SPAN.

large institutional players, which are not members of a clearing house, have special arrangements (often through off-shore accounts) to essentially get the same terms as clearing house members. Therefore, the analysis of the margins on customer accounts (retail investors) and on brokers' proprietary accounts should be sufficient to uncover the impact of the margining system on the key players in the option market.

3.1. The CBOE minimum margins for customer accounts

The margin requirements for customers depend on the type of option strategy and on whether the short positions are covered by a matching position in the underlying asset. The margin for a naked position is determined on the basis of the option sale proceeds, plus a percentage of the value of the underlying asset, less the dollar amount by which the contract is OTM, if any.[10] Specifically, for a naked position in a call or put option, the margin requirement at time t can be found by applying the following simple rules:

- Call: $M_t = \max(C_t + \alpha S_t - (K - S_t | K > S_t), C_t + \beta S_t)$ and
- Put: $M_t = \max(P_t + \alpha S_t - (S_t - K | S_t > K), P_t + \beta K)$

where C_t and P_t are the option settlement prices, α and β are parameters between 0 and 1, S_t is the underlying price at the end of the day, and K is the strike price of the option. Delta-hedged positions are subject to a composite margin rule: one minus delta of the naked-put margin plus the margin on the underlying. Combinations are instead margined by an amount corresponding to the requirement on the call or the put, whichever is greater, plus the proceeds of the other side.

The quantification of the parameters α and β depends on the type of underlying asset and on the investor trading in the options. For the S&P 500, the CBOE Margin Manual specifies $\alpha = 15\%$ and $\beta = 10\%$. Nonetheless, brokers may charge clients with higher margins. For example, E-Trade imposes margin requirements to individual investors according to the same formula but with α and β equal to 40% and 35%, respectively.

3.2. The CME minimum margins for member proprietary accounts and large institutional investors

The SPAN system is a scenario-based algorithm that computes the margins on the basis of the overall risk of a specific account. The purpose of SPAN is to find what the highest possible loss of a portfolio would be under a variety of scenarios. These scenarios are constructed by considering changes in the price of the underlying and in the level of volatility. At the end of the day, the assets in the account are re-evaluated using an option pricing model (the default model is Black, 1976) under a range of underlying price and volatility movements. The scenario losses and profits of the open positions of a particular

[10] A complete description of how to determine margin requirements for various strategies can be found in the CBOE Margin Manual, which can be downloaded from the website: www.cboe.com/LearnCenter/pdf/margin2-00.pdf. Note also that, in July 2005, the SEC approved a set of new rules regarding portfolio margining and cross-margining for index options positions of certain customers, thus making the new margining system closer to the one adopted by the CME, which will be discussed in the next section.

account are then examined together and the highest possible loss is chosen to be the minimum margin requirement for that account.[11]

For example, the current price range for the S&P 500 futures is ±\$80, while the volatility range is ±%5.[12] SPAN generates 14 scenarios by considering combinations of seven price changes (±\$80, $\pm\frac{2}{3} \times \$80$, $\pm\frac{1}{3} \times \$80$, 0) and the two volatility changes. In order to account for the impact of extreme price movements on deep OTM short positions, SPAN also computes potential losses in two additional scenarios, which correspond to a price change of $\pm 3 \times \$80$. In these last two scenarios, only one-third of the potential loss is taken into account to determine margins.

3.3. Comparison of the two margining systems

To offer a simple comparison between the two margining systems, we simulate the behavior of the margin account for a short position in one put option contract. We compute the margin for an ATM option with a maturity of 45 days. The underlying price is \$100 and the volatility level is 20%. The option price is computed using the Black (1976) formula, using an interest rate equal to 5%. The initial margin requirement is \$17.80 and \$9.12 for the CBOE and the CME margin system, respectively. We perform a scenario analysis of the margin account by simulating movements in the underlying and volatility levels. We allow the underlying value to range between \$80 and \$100 and the volatility level between 20% and 50% and plot the value of the maintenance margin in Panel A of Fig. 1 and the corresponding margin calls in Panel B. Margin calls are computed by subtracting the initial margin from the maintenance requirement. As the underlying price decreases and the potential loss incurred by the short position in the put becomes larger the maintenance margin also grows. The value of the CBOE maintenance margin is always higher than the corresponding value for the CME. However, since the CME initial margin is lower than the CBOE initial margin, the CME margin calls are higher than the corresponding CBOE margin calls.

3.4. Margin haircuts

As a first measure of the amount of margins that an investor would have been asked to maintain in the sample, we calculate the "haircut" ratio, which represents the amount by which the required margin exceeds the price at which the option was written. The haircut corresponds to the investor's equity in the option position. We compute the ratio as $(M_t - V_0)/V_0$, where M_t is the margin at the end of each day t, and V_0 is equal to the proceeds received at the beginning of the month: P_0 for naked and delta-hedged puts,[13] and $C_0 + P_0$ for straddles and strangles.

[11] A more detailed description of how SPAN works can be found on the CME webpage at the following URL: http://www.cme.com/clearing/rmspan/span/compont2480.html.

[12] The range of possible movements in the underlying security is selected by the Board of Directors and the Performance Bond Sub-Committee in order to match the 99th percentile of the historical distribution of daily price changes. The time series of the SCAN range parameters were obtained directly from the CME.

[13] Note that the proceeds from writing a delta-hedged put is equal to the put price minus the delta of the underlying value. We decided to compute the haircut as a percentage of only the put price to make the haircut ratio of a delta-hedged put comparable to the corresponding ratio of a naked put.

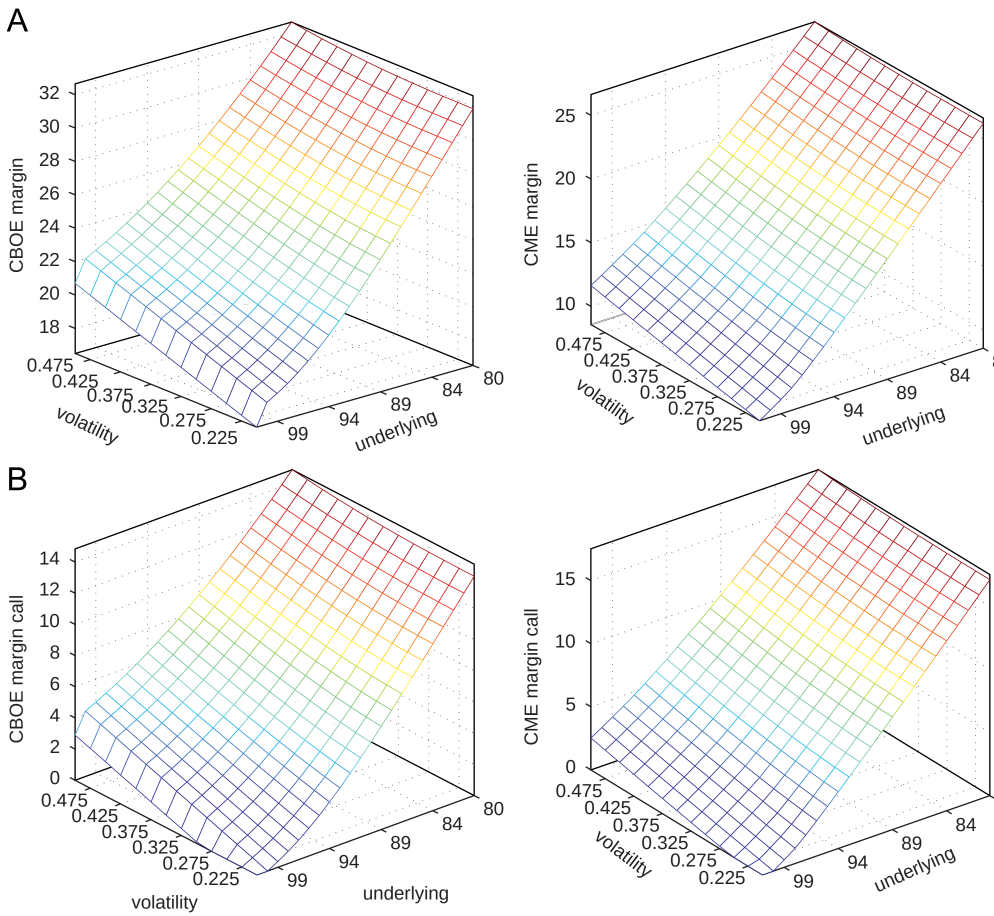

Fig. 1. Simulated margin requirements. We consider an ATM put option with a maturity of 45 days. The underlying price is $100 and the volatility level is 20%. The option price is computed using the Black (1976) formula, using an interest rate equal to 5%. In Panel A, we plot the value of the maintenance margin when the underlying price and volatility move. In Panel B, we plot the corresponding margin calls, which are computed by subtracting the initial margin from the maintenance requirement. We allow the underlying price to range between $80 and $110 and the volatility between 10% and 50%. The margin call is computed by subtracting the value of the initial margin requirement, which is equal to $17.80 and $9.12 for the CBOE and the CME margin system, respectively, from the maintenance margin: (a) Panel A: maintenance margin and (b) Panel B: margin call.

In what follows, we use the CBOE margins as a proxy for the margin requirement for customers, and the CME margins as a proxy for the proprietary account margin requirements for clearing house members and large institutional investors. In Table 5, we report the mean, median, standard deviation, minimum, and maximum of the haircut ratio for customers (left part of the table) and proprietary accounts (right part of the table).

On average, a customer must deposit $6.60 as margin (in addition to the option sale proceeds) for every dollar received from writing ATM puts. In our sample, the maximum historical haircut ratio for those options, equals 13.8. To put this into perspective, we can interpret the inverse of the haircut ratio as the maximum percentage of the investor's

Table 5
Margin "haircut".

	CBOE margins					CME margins				
	Mean	Med.	Std	Min.	Max	Mean	Med.	Std	Min.	Max.
Put ATM	6.6	6.3	2.3	1.9	13.8	2.6	2.2	1.4	0.6	11.6
Put 5% OTM	13.5	11.0	8.0	2.0	46.9	5.5	4.5	3.7	0.8	21.7
Put 10% OTM	29.6	22.5	22.9	2.3	116.7	9.9	6.9	8.9	0.8	51.4
Delta Put ATM	5.2	4.9	1.9	1.2	10.5	1.3	1.1	0.8	0.2	6.9
Delta Put 5% OTM	13.0	10.5	7.9	1.6	44.1	4.1	3.2	3.2	0.3	17.7
Delta Put 10% OTM	29.6	22.3	23.0	2.1	116.9	8.5	5.4	8.3	0.3	45.0
Straddle ATM	3.7	3.5	1.4	1.1	11.2	1.3	1.0	0.9	0.2	9.5
Strangle 5% OTM	10.2	8.1	9.6	1.1	172.2	3.9	2.7	4.2	0.3	69.1
Strangle 10% OTM	18.7	13.2	16.3	1.5	190.4	6.7	4.1	6.6	0.5	79.0

For each option, this table reports the mean, median, standard deviation, minimum, and maximum of the margin haircut, which is the ratio of the margin to the option's value at the beginning of the month when the trade is implemented, $(M_t - V_0)/V_0$. The CBOE margins (right part of the table) are used as a proxy for the margin requirement for customers, and the CME margins (left part of the table) as a proxy for the proprietary accounts of a clearing house member. Option and S&P 500 future closing prices were sampled daily between January 1985 and May 2001. The data are provided by the Chicago Mercantile Exchange through the Institute for Financial Markets. All options are American.

wealth that could be allocated to the option trade if all the wealth was committed to the margin account. For example, to maintain an open position in the ATM put and hence to be able to post the maximum margin call in the sample, the investor would only be able to write contracts for an amount equal to 7.2% of the wealth. A clearing house member would have to post on average \$2.60 per dollar of options, and \$11.60 in the worst case scenario.

Note that under CBOE rules, the margining of a delta-hedged position is quite expensive: only delta of the option position is in fact exempt from margins, while the entire short position in the underlying is subject to REG-T margins. Therefore, the haircut ratios of delta-hedged positions are very close to the corresponding ratios for naked positions. Under CME rules, this does not happen, although the requirements are still quite onerous. Haircuts for combination strategies are slightly lower than the corresponding ratios for naked and delta-hedged positions.

This analysis does not show that margin requirements preclude investors from writing options. It does, however, show that margins have a real impact for option traders by limiting their exposure to option strategies. Table 5 also offers evidence that the difference in the requirements imposed to different classes of investors can be quite drastic: the cost of writing an option for an individual investor is two to three times higher than the cost that an institutional investor faces.

4. Impact of margin requirements

We conjecture that margins influence options trading along two dimensions: they limit the number of contracts that an investor can write (strategy execution), and they frequently force the investor to close down positions and to take losses (strategy profitability).

We test this conjecture in the rest of the paper by analyzing a realistic zero-cost strategy. We assume that at the beginning of every month the investor borrows $1 and allocates that amount to a risk-free rate account that she uses to cover margins.[14] Option contracts are written for an amount equivalent to a fraction of the one dollar. We refer to this quantity as the ‘‘target’’ portfolio weight. The initial margin requirement is determined on the base of the number of contracts corresponding to the target weight.

In implementing the strategy, we assume that, during the month, access to the credit market is limited so that the investor's availability to capital cannot exceed what initially borrowed. This is a key assumption without that margins never have a real effect on trading strategy. However, it is not unrealistic to presume that access to capital becomes more difficult in instances which would trigger margin calls: high volatility and or large negative market returns. For example, Brunnermeier and Pedersen (2008) study flight to liquidity/quality in an economy characterized by trading frictions similar to those studied in this paper. They conclude that margins exacerbate funding liquidity in adverse market conditions. Therefore, in our setting, margin calls are met by liquidating the investment in the risk-free rate account. When the balance of the risk-free rate account is not sufficient to meet the margin call, the option position is liquidated at the option's closing price. At that point, we allow the investor to open a new position so that the new margin due does not exceed 90% of the available wealth. The 90% level is chosen to prevent that a new margin call following a small adverse movement of the underlying price leads to another immediate liquidation. At the end of the month, we close the option position and add the proceeds to the balance of the risk-free rate account. The percentage difference between this quantity and the one dollar initially borrowed represents the strategy return for the month. Finally, we repeat the exercise for each month in the sample and obtain time-series of returns.

4.1. Impact on execution

We analyze the impact of margins on the execution of the strategies by computing the investment that can be effectively achieved in the presence of margins (‘‘effective’’ option portfolio weight). The effective portfolio weight differs from the target weight in the months in which the investor is unable to meet the minimum margin requirement either at the incipit of the strategy (at the beginning of the month) or during the holding period. The difference between effective and target weight represents the impediment that the margins cause to the strategy implementation. We conjecture that a testable implication of the limits to arbitrage theory is that the impediments caused by frictions should be more economically important when the investor is more aggressive in pursuing the strategy. We seek a validation to our conjecture by testing whether the difference between target and effective weight is increasing with the target weight.

The analysis is conducted considering different target weights from 2.5% to 20% and the results are reported in Table 6. Empirical distributions for the quantity of interest are obtained through bootstrapping. Panel A tabulates effective weights for each strategy. The

[14]The investment opportunity set includes the risk-free rate and the option strategy. One possibility would be to include the market portfolio. We analyze this case in Section 5.

Table 6
Impact of margins on execution and profitability of option strategies.

Target weight	CBOE margins				CME margins			
	2.5%	5%	10%	20%	2.5%	5%	10%	20%
Panel A: Effective weight								
Put ATM	2.50	5.00	9.80**	14.85**	2.50	5.00	10.00**	19.74**
Put 5% OTM	2.50	4.74**	7.74**	9.74**	2.50	5.00	9.69**	16.66**
Put 10% OTM	2.25	3.59**	4.86**	5.58**	2.49**	4.81**	8.53**	13.10**
Delta Put ATM	2.50	5.00	9.99	16.81**	2.50	5.00	10.00	19.99
Delta Put 5% OTM	2.52	4.86**	8.15**	10.36**	2.50	5.00	10.10	18.65**
Delta Put 10% OTM	2.31**	3.87**	5.07**	5.49**	2.56	5.02	9.28**	14.73**
Straddle ATM	2.50	5.00	9.99**	19.07**	2.50	5.00	10.00**	19.98**
Strangle 5% OTM	2.46**	4.75**	8.23**	11.61**	2.47**	4.92**	9.41**	15.35**
Strangle 10% OTM	2.37**	4.16**	6.20**	7.27**	2.45**	4.60**	7.31**	9.34**
Panel B: Months with a forced rescaling (out of 198)								
Put ATM	0**	0**	28**	164**	0**	0**	2	29**
Put 5% OTM	4**	48**	133**	186**	0**	2	37**	111**
Put 10% OTM	50**	119**	177**	192**	6**	34**	86**	147**
Delta Put ATM	0**	35**	162**	196**	0**	0**	0**	2
Delta Put 5% OTM	39**	135**	194**	197**	0**	0**	22**	73**
Delta Put 10% OTM	105**	183**	195**	197**	5**	28**	70**	124**
Straddle ATM	0**	0**	2	50**	0**	0**	1	3*
Strangle 5% OTM	5**	31**	99**	171**	4**	5**	45**	116**
Strangle 10% OTM	25**	81**	160**	186**	11**	40**	119**	180**
Panel C: Percentage mean return								
Put ATM	0.45**	0.93**	1.56*	1.60*	0.45**	0.93**	1.66**	2.81*
Put 5% OTM	0.74**	1.00*	1.36*	1.35	0.79**	1.43**	2.43**	2.97**
Put 10% OTM	0.34	1.03**	1.59**	1.36	0.45	1.57**	2.33**	2.61**
Delta Put ATM	0.16	0.35*	0.49	0.53*	0.16	0.33*	0.69*	0.99

Delta Put 5% OTM	0.48**	0.63**	0.71**	0.73**	0.53**	1.08**	1.39	1.95
Delta Put 10% OTM	0.34	0.46	0.51	0.53	0.14	0.25	1.53**	0.31
Straddle ATM	0.17*	0.36**	0.52	0.97	0.17*	0.36**	0.52	1.00
Strangle 5% OTM	0.55**	0.98**	0.94	0.99	0.56**	1.13**	1.66**	1.97**
Strangle 10% OTM	0.80**	1.07**	1.26	1.75**	0.87**	1.62**	1.78**	2.37**
Panel D: Sharpe ratio								
Put ATM	0.19**	0.20**	0.14*	0.12*	0.19**	0.20**	0.15**	0.13*
Put 5% OTM	0.24**	0.13*	0.15*	0.12	0.26**	0.18**	0.18**	0.16**
Put 10% OTM	0.04	0.18**	0.25**	0.12	0.05	0.22**	0.19**	0.16**
Delta Put ATM	0.12	0.14*	0.12	0.13*	0.12	0.12*	0.13*	0.06
Delta Put 5% OTM	0.23**	0.16**	0.17**	0.18**	0.25**	0.25**	0.12	0.11
Delta Put 10% OTM	0.08	0.09	0.10	0.10	0.02	0.01	0.17**	0.01
Straddle ATM	0.14*	0.15**	0.07	0.07	0.14*	0.15**	0.07	0.07
Strangle 5% OTM	0.29**	0.25**	0.09	0.10	0.29**	0.29**	0.16**	0.16**
Strangle 10% OTM	0.35**	0.24**	0.12	0.19**	0.38**	0.36**	0.16**	0.23**
Panel E: Leland alpha								
Put ATM	0.09	0.20	−0.16	−0.58	0.09	0.20	−0.11	−0.65
Put 5% OTM	0.25	−0.19	−0.13	−0.51	0.30	0.23	0.35	0.08
Put 10% OTM	−0.77	0.16	0.61*	−0.29	−0.68	0.53	0.46	0.11
Delta Put ATM	0.03	0.11	0.07	0.12	0.03	0.08	0.19	−0.62
Delta Put 5% OTM	0.30	0.26	0.31	0.33	0.35*	0.73*	0.22	0.13
Delta Put 10% OTM	−0.05	−0.02	0.03	0.05	−0.70	−1.35	0.89	−2.40
Straddle ATM	0.08	0.19	−0.12	−0.27	0.08	0.19	−0.11	−0.30
Strangle 5% OTM	0.45**	0.77**	0.12	0.24	0.45**	0.92**	0.86	1.27
Strangle 10% OTM	0.80**	1.09**	1.25	1.83	0.86**	1.61**	1.69	2.36*
Panel F: MPPM								
Put ATM	−0.01	0.01	−6.67	−6.72	−0.01	0.01	−6.67	−6.93
Put 5% OTM	0.01	−2.03	−0.45	−2.68	0.02	−1.99	−6.68	−8.72**
Put 10% OTM	−6.67	−0.02	0.02	−6.67	−6.67	−0.06	−6.73	−6.78
Delta Put ATM	−0.04**	−0.03	−0.04	−0.03	−0.04**	−0.03	−0.04	−6.69
Delta Put 5% OTM	−0.01	−0.02	−0.02	−0.02	−0.00	0.02	−6.69	−6.95*
Delta Put 10% OTM	−0.09	−0.16	−0.16	−0.16	−6.69	−6.66	−0.16	−9.82**

Table 6 (*continued*)

Target weight	CBOE margins				CME margins			
	2.5%	5%	10%	20%	2.5%	5%	10%	20%
Straddle ATM	−0.04**	−0.02	−1.47	−6.67	−0.04**	−0.02	−1.47	−6.68
Strangle 5% OTM	0.00	0.03	−6.67	−0.88	0.01	0.05	−6.65	−0.30
Strangle 10% OTM	0.03	0.03	−6.68	−1.33	0.04	0.09	−6.67	−1.67

This table analyzes the impact of margin calls on the returns to a portfolio of the risk-free asset and the option strategies. We assume that the strategy is implemented at the beginning of each month. If it is not possible to open a position for the desired percentage of wealth, the target weight, because minimum margin requirements are in excess of wealth, the option strategy weight is recalculated so that the margin due by the investor does not exceed 90% of the available wealth. The amount invested in the risk-free asset is posted as margin (possibly in excess of the minimum required), and assumed to return the risk-free rate. During the month, if the investor faces a margin call due to an adverse movement in the S&P 500, it is met up to availability in the cash account. If and when the investment in the risk-free rate account is exhausted by margin calls, the option position is liquidated, and a loss is realized. We proceed by opening a new position wherein the option strategy weight is recalculated so that the margin due by the investor does not exceed 90% of the available wealth at the end of the day. Option contracts are written for a dollar amount equivalent to a fraction of one dollar. We refer to this quantity as the target weight. We repeat the analysis for different levels of the target weight: 2.5%, 5%, 10%, and 20%. If a liquidation is necessary during the month, the effective proportion of capital invested in writing the option could be less than the target weight. We refer to this amount as the effective weight. We report effective weights in Panel A, the number of months with a forced rescaling in Panel B, the average returns in Panel C, Sharpe ratios in Panel D, and Leland's alphas in Panel E, and the MPPM in Panle F. As a measure of transaction cost we compute the difference between the average returns computed at mid-point prices and the average returns computed from bid to ask, which are reported in Table 4. The CBOE margins are used as a proxy for the margin requirement for customers, and the CME margins as a proxy for the proprietary accounts of a clearing house member. Significance levels corresponding to bootstrapped *p*-values are also reported: * and ** indicate 10% and 5% significance levels, respectively. The null hypothesis is against the target weight for Panel A and against 0 for Panels B, C, D, E, and F. Option and S&P 500 future closing prices were sampled daily between January 1985 and May 2001. The data are provided by the Chicago Mercantile Exchange through the Institute for Financial Markets. All options are American.

results reported in the table confirm our conjecture: if the target weight is small, 2.5% of capital, the difference between target and effective weight is small. For target weights larger than 2.5%, as is also suggested by the analysis of the haircut ratios in Table 5, the impact of margins is greater for lower moneyness options. If the target weight is high, 20% or more, the effect of margins on the allocation of capital to option strategies can be economically very large. On the one hand, for ATM options margins have little impact on strategy execution. For example, if the target weight is 20%, in the case of the far ATM straddle, the difference between the target and the effective weight is 0.83% for CBOE customers and 0.02% for CME members. On the other hand, the impact is quite large when OTM options are considered. For example, if the target weight is 20%, in the case of the 5% OTM put, the difference between target and effective weight is 10.2% for CBOE customers and 3.4% for CME members. That represents a 50% and 20% potential profit reduction, respectively.

We formally confirm the result by estimating the correlation between the level of the target weight and the difference between the target and the effective weight. First, we compute the Spearman rank correlation coefficient. The estimate of the correlation coefficient is equal to 0.67 and is highly statistically significant. Second, since the magnitude of the difference between the target and the effective weight varies across different strategies, we estimate a linear regression, of target weight on the difference, which allows to control for a variety of fixed effects: puts versus hedges versus combinations, CBOE margins versus CME margins. After controlling for these characteristics, the estimated coefficient on the target weight is equal to 0.345 and is highly statistically significant (t-stat of 6.1).

In Panel B of Table 6, we report the number of months during which the investor is unable to cover the initial or the maintenance requirement corresponding to the target weight. To simplify notation we refer to all those cases as "rescalings." The pattern is similar to what suggested by the results in Panel A: failures to comply with the requirements are more numerous for low moneyness strategies. The number of rescalings is quite high: if the target weight is equal to 20%, OTM strategies endure a rescaling in almost every month of the sample.

4.2. Impact on profitability

Margins have an effect on the profitability of the strategies through two channels. First, a positive difference between target and effective weight represents an opportunity cost to the investor in the form of missed profits that originate from the fact that capital has to be allocated to the margin account instead of to trading options. Second, since margin calls happen when the market is moving against the investor's position in the option (underlying price decreases or volatility increases), liquidations will also have the effect of forcing the investor to realize losses. In Panel C of Table 6, we report the average strategy returns. A higher target weight leads to a larger average return. However, the average return corresponding to a target weight of 10% is not twice as large as the average return of a 5% exposure. That is especially true for those strategies for which margins matter the most. For example, the average return of the 10% OTM strangle for a CME member investor rises from 1.78% to 2.37% when the portfolio weight increases from 10% to 20%.

We also compute performance measures that take some dimension of risk into account. We report Sharpe ratios in Panel D of Table 6,[15] Leland's alpha in Panel E,[16] and the MPPM of Ingersoll et al. (2007) in Panel F.[17]

With very few exceptions, the performance measures decrease when moving from a smaller to a larger option portfolio weight. For example, the Sharpe ratio corresponding to a target weight of 20% is lower than the Sharpe ratio corresponding to a target weight of 2.5% for approximately two-thirds of the strategies. A similar pattern is observed for the other profitability measures: the percentage is about 70% for the Leland's alpha and about 90% for the MPPM. For example, let's consider the ATM straddle, which is an option strategy which performance is found to be most problematic in the literature (see, for example, Bates, 2007). When going from a 2.5% to a 20% target weight, the SR decreases from 0.14 to 0.07, the Leland alpha from 0.08 to $-$0.27, and the MPPM from $-$0.04 to $-$6.67.

Some of these performance measures are reported in other studies: for example Bondarenko (2003), Coval and Shumway (2001), Jones (2006), and Driessen and Maenhout (2007). These studies analyze strategy returns as if there were no margin requirements. Let's consider for example the case of the Leland model. The above mentioned studies find that alphas for put option strategies are really large and statistically significant.[18] We find a different result because we consider returns after margins are taken into account. Examining the relation between the allocation sought by the investor and the size and significance of the alphas we notice that a larger target weight usually implies a lower alpha and a lower significance level. The result is due to the fact that the covariance of the strategy returns with the market increases with the strategy exposure, leading to lower or zero alphas. The covariance increases because the return on the strategy is negatively affected by the inability of the investor to cover margin calls, which tend to happen when the market return is negative.

To summarize, a rise in volatility and/or a drop in the underlying price causes an increase in the margin requirement. If investors do not have easy access to capital, an increase in maintenance margins severely affects the execution of option strategies that involve writing options. The investor is forced to realize losses, even if the strategy could ultimately lead to a positive return. The profitability of the strategies is therefore affected.

5. Impact of margin requirements: three assets

In the previous section, we show that the amount of capital that must be devoted to margins is high relative to the price of an option contract. The conclusion that we can draw is that the opportunity cost related to maintaining margins is the key in trading/writing options. In the economic setting described in Section 4, the opportunity cost arises because

[15]Note that, since the portfolio is short in options and long in the risk-free rate account for different amounts, the strategy Sharpe ratios will not be exactly equal to those reported in Table 2.

[16]Results for alpha derived from the CAPM and the Fama and French (1993) three factors model are very similar and can be obtained from the authors upon request.

[17]Ingersoll et al. (2007) derive a performance measure that cannot be manipulated by information-unrelated trades: $MPPM = (1/(1-\rho)\Delta t)\log((1/T)\sum_{t=1}^{T}[(1+r_t)/(1+rf_t)]^{1-\rho})$, where ρ is a coefficient that should be chosen to make holding the benchmark optimal. We set it equal to 2 as suggested by the authors. The corresponding MPPM for the market portfolio is then 0.

[18]Driessen and Maenhout (2007) include CBOE margins in parts of their analysis.

capital has to be invested in the margin account with a return equal to the short-term interest rate (typically the rate on a Treasury bill).

In this section, we modify the economic setting of Section 4 in two ways. First, we include S&P 500 futures in the investment opportunity set. Second, we consider different possibilities as to what exposure the investor can take in the futures: the investor can take a positive exposure in an attempt to increase the return of the margin account; or the investor can take a negative exposure in an attempt to reduce the margin by taking a hedge in the underlying.

Therefore, with this analysis, we study whether the inclusion of a third asset can improve on the ability of the investor to trade options by reducing the opportunity cost related to maintaining margins. In other words, we are seeking further verification that margins do have an impact on trading options even when the investor is allowed to try to minimize the opportunity cost of maintaining the margin account by using as collateral an asset that has a higher average return then the risk-free rate.

As noted above, we study several scenarios that comprise the instance in which the investor takes a *short* position in one futures contract for each written option contract, in which case the put options are completely covered. We refer to this case as complete coverage. For symmetry we also analyze the case where the investor takes a *long* position in one futures contract for each written option contract (negative coverage). Therefore, in our experiment, the possible option portfolio weights vary between −2.5% and −20% (as before), while the coverage ratio varies between 1 (the put option is completely covered) and −1 (long position in the underlying for an amount equivalent to a full cover) with increments of 0.5. The results for exact delta-hedged strategies are contained in the previous sections. For example, let's consider the case of an investor that writes 10 put option contracts. A coverage ratio of 0.5 would imply covering the position with five futures contracts, while a coverage ratio of −0.5 would imply a long position of five futures contract. Note that the positions are all relative to an initial investment of $1. Scaling up that amount affects the number of contracts but does not change the returns.

We report the results of the analysis for the 5% OTM put option strategy in Table 7.[19]

5.1. Impact on execution

As we can see from Panel A of the Table 7, the margins have an impact on the execution of option strategies whether the futures is traded or not. Across different coverage ratios, the difference between the target and the effective option weight is bigger in the cases when the investor seeks to write options more aggressively (higher target weights). Across option target weights, positive or negative coverage does not increase the effective option weight. For the CME margining system, which is based on projected losses from the total portfolio, the maximum exposure to options is obtained with zero coverage. The result is due to the fact that the CME margins take into account the correlation between the option and the underlying payoff. The very large exposure to the underlying, reported in Panel B, has in fact a pervasive effect on the capital that is available to cover margins. The hedge (positive coverage) comes at a great cost: the large negative position in the underlying that is necessary to cover the option generates enough losses to significantly decrease the capital

[19]Results for all the other strategies are not reported to limit the number of tables but they are available upon request.

Table 7
Impact of margins on execution and profitability of option strategies: three assets (risk-free rate, 5% OTM put, and S&P 500 futures).

Target weight	CBOE margins				CME margins			
	−2.5%	−5%	−10%	−20%	−2.5%	−5%	−10%	−20%
Panel A: Effective weight × 100								
Coverage								
1.0	2.50	4.85**	8.15**	11.44**	2.50	4.66**	7.36**	10.02**
0.5	2.50	4.84**	7.72**	10.28**	2.50	5.00	9.39**	15.12**
0.0	2.50	4.74**	7.74**	9.74**	2.50	5.00	9.69**	16.66**
−0.5	2.48**	4.45**	6.51**	7.32**	2.50	4.92**	8.66**	12.84**
−1.0	2.44**	4.09**	5.39**	5.82**	2.50	4.72**	7.51**	9.72**
Panel B: Market weight								
1.0	−3.31**	−6.70**	−11.06**	−14.17**	−3.31**	−6.75**	−10.97**	−13.53**
0.5	−1.64**	−3.11**	−4.52**	−5.28**	−1.64**	−3.31**	−6.75**	−11.03**
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
−0.5	1.55**	2.36**	2.94**	3.06**	1.62**	3.01**	4.79**	6.03**
−1.0	2.91**	4.15**	4.81**	4.90**	3.21**	5.57**	7.56**	8.52**
Panel C: Mean return								
1.0	−0.64	−1.45	−2.36	−4.12	.−0.64	−1.47	−2.43	−4.39
0.5	0.07	0.12	0.12	−0.48	0.07	0.17	0.10	−0.17
0.0	0.74**	1.00*	1.36*	1.35	0.79**	1.43**	2.43**	2.97**
−0.5	1.38**	2.12**	2.37*	2.40*	1.50**	2.49**	4.25**	5.64**
−1.0	1.85*	3.02**	3.11*	2.88*	2.04*	3.89**	5.32**	5.91**
Panel D: Sharpe ratio								
1.0	−0.068	−0.077	−0.077	−0.103	−0.068	−0.077	−0.079	−0.115
0.5	0.017	0.014	0.010	−0.033	0.017	0.019	0.006	−0.006
0.0	0.240**	0.127*	0.147*	0.120	0.256**	0.181**	0.185**	0.159**
−0.5	0.173**	0.166**	0.138*	0.130*	0.189**	0.151**	0.175**	0.168**
−1.0	0.139*	0.162**	0.135*	0.122*	0.141*	0.162**	0.157**	0.144**
Panel E: Leland α								
1.0	0.48	0.78	1.50	1.12	0.48	0.76	1.45	0.71
0.5	0.39	0.72	0.96	0.40	0.39	0.80	1.35	1.94
0.0	0.25	−0.19	−0.13	−0.51	0.30	0.23	0.35	0.08
−0.5	0.08	−0.02	−0.56	−0.77*	0.20	−0.19	0.50	0.53
−1.0	−0.31	0.04	−0.66	−1.03	−0.28	0.21	0.26	−0.19
Panel F: MPPM								
1.0	−0.31**	−1.04**	−2.93**	−5.88**	−0.31**	−1.10**	−3.33**	−5.69**
0.5	−0.08**	−0.17**	−0.34**	−0.54**	−0.08**	−0.18**	−0.73**	−2.84**
0.0	0.01	−2.03	−0.45	−2.68	0.02	−1.99	−6.68	−8.72**
−0.5	−0.04	−0.21	−6.77*	−6.53**	−0.03	−6.75	−1.27**	−7.49**
−1.0	−0.59	−0.47**	−1.71**	−3.38**	−6.71	−3.01**	−3.50**	−11.06**

This table analyzes the impact of margin calls on the returns to a portfolio of the risk-free asset, the S&P 500 futures, and the 5% OTM put option. The implementation of the strategy is identical to the case described in Table 6. The number of futures contracts that are included in the portfolio is determined as a function of the option position. The scenarios we consider vary between the case where the investor takes a *short* position in one futures contract for each written option contract (complete coverage) to the case where the investor takes a *long* position in one futures contract for each written option contract (negative coverage). We repeat the analysis for different levels of the target weight: 2.5%, 5%, 10%, and 20%. The coverage ratio varies between 1 (the put option is completely covered) and −1 (long position in the underlying for an amount equivalent to a full cover) with increments of 0.5. We report effective weights in Panel A, the futures portfolio weights in Panel B, average returns in Panel C, Sharpe ratios in Panel D, Leland's alpha in Panel E, and MPPM in Panel F. Significance levels corresponding to bootstrapped *p*-values are also reported: * and ** indicate 10% and 5% significance levels, respectively. The null hypothesis is against the target weight for Panel A and against 0 for the other panels. Option and S&P 500 future closing prices were sampled daily between January 1985 and May 2001. The data are provided by the Chicago Mercantile Exchange through the Institute for Financial Markets. All options are American.

that is available to the investor. On the other hand, the long positions in the underlying (negative coverage) produce losses precisely when the option position is losing money (market drops), thus accentuating the portfolio down-side risk, and hence increasing margins.

5.2. Impact on profitability

Examining the profitability measures, we note that the best performance is often obtained with zero coverage and for small target option weight. The sign and magnitude of the average returns is inversely related to the coverage ratio: positive coverage (short positions in the futures) produces negative average returns, while negative coverage is associated with positive average returns. When margins are taken into account, perfect coverage of the option is quite expensive: for example, full coverage of a −10% option position produces an average return of −2.43% per month. This is essentially due to the fact that the futures contracts necessary to implement the cover correspond to an exposure to the underlying of −11 times of the available capital. (Such an exposure can only be obtained through futures.)

Considering the combinations that produce positive returns, the Sharpe ratios tend to decrease going from zero to negative coverage. Ingersoll et al. (2007) show that Sharpe ratios can be easily manipulated by using options. The measure they propose (MPPM) is especially adequate to evaluate strategy performance in this setting wherein options are paired with positions in the S&P 500. The MPPM is in fact calibrated so that a portfolio that would be entirely invested in the S&P 500 would have a score equal to zero. As we can see from Panel F of Table 7, MPPM is decreasing with the option weight and the absolute value of the coverage. The measure is positive or close to zero only for a very small position (2.5% in the option and zero coverage) in the option and is negative and large for extreme positions.

In summary, an investor is better off trading a smaller number of option contracts as the performance tends to deteriorate when larger exposures to the options are sought. Results for all the other strategies (puts, straddles, and strangles) are similar both quantitatively and qualitatively.

5.2.1. Regression approach

In order to gather an overall perspective we frame the analysis in the context of a linear regression. We pool the estimated performance measures for each pair of option weights and coverage ratios for the six basic strategies (three naked puts and the straddle and the two strangles).

We run a panel regression of the performance measure on the option target weight (w_{op}) and the coverage ratio (*cover*) controlling for various fixed effects: CBOE versus CME, put versus combination, and the three levels of moneyness. We run the following regression:

$$X = \alpha + \beta\ w_{op} + \gamma\ cover + \varepsilon,$$

where $X = \{w^*_{op},$ SR, Leland α, MPPM$\}$. w^*_{op} is defined as the difference between the effective and the target weight. For convenience of interpretation, we use the absolute value of w_{op} as the independent variable, so that a larger number represents a larger option portfolio weight.

Table 8
Impact of margins on execution and profitability of option strategies, linear regression.

	w^*_{op}	SR	LEL	MPPM
w_{op}	−0.474	−0.195	−0.261	−23.623
	(−15.25)	(−2.52)	(−3.90)	(−10.42)
cover	0.005	−0.155	0.019	0.999
	(2.28)	(−24.47)	(3.29)	(4.93)
R^2	0.692	0.631	0.182	0.431

We pool the estimated performance measures for each pair of option weights and coverage ratios for the six basic strategies (three naked puts, the straddle, and two strangles). We run a fixed effect panel regression in which we control for various characteristic: CBOE versus CME, put versus combination, and the three levels of moneyness:

$$X = \alpha + \beta w_{op} + \gamma\ cover + \varepsilon,$$

where $X = \{w^*_{op}$, SR, Leland α (LEL), MPPM$\}$. w^*_{op} is defined as the difference between the effective and the target weight. For convenience of interpretation, we use the absolute value of the target weight w_{op} as the independent variable, so that a larger number represents a larger option portfolio weight. *cover* is the coverage ratio. Since there are twenty combinations of option weight and coverage ratios for each strategy, and there are six basic strategies for each of the two margining systems, each regression is based on a sample of 240 observations. Clustered and heteroskedasticity consistent standard errors are used to compute the *t*-statistics, which are reported in parenthesis. Constants and the fixed-effect dummies are not reported.

Since there are 20 combinations of option weight and coverage ratios for each strategy and there are six basic strategies for each of the two margining systems, each regression is based on a sample of 240 observations. Our null hypothesis (margins do not have any impact) is that the strategy performance improves or does not deteriorate by increasing the option exposure (w_{op}). A statistically significant negative estimated coefficient ($\hat{\beta}$) thus leads to rejection of the null hypothesis. The results are reported in Table 8.

The estimated slope coefficients of the option portfolio weight (w_{op}) are all negative. The results of this analysis are strongly supportive of our conjecture: increasing the portfolio exposure to the option and controlling for the level of coverage leads to a deterioration of the portfolio profitability and to a bigger difference between effective and target weight. The *t*-statistics confirm that the estimates are negative at conventional significance levels.

6. Conclusion

Previous studies report unusually high returns to option strategies that involve writing put options. The contribution of this paper is to show that the returns realizable by investors subject to the margining systems are not as large as previously documented. We show that, if margins are taken into account, part of the "un-margined" returns is not available to investors. Therefore, while volatility and jump risk premia are priced into option prices, limits to arbitrage, represented by transaction costs and margin requirements, might blunt the effectiveness of option markets for risk sharing among investors.

The fact that liquidity in the option market has traditionally been supplied by market-makers (Bates, 2001; Bollen and Whaley, 2004; Garleanu et al., 2005) provides the economic rationale for the importance of margin requirements in explaining option prices.

In Garleanu et al. (2005), high prices are driven by market-makers who charge a premium because they are unable to completely hedge away the risk involved with an unbalanced inventory. We argue that, despite being attracted by high prices, other investors are limited from supplying liquidity to the market by the fact that they have to maintain margins. Lack of liquidity allows high prices to persist in the market. Although we do not examine flights to liquidity, the argument that is proposed in this study is similar to that presented by Garleanu and Pedersen (2007) and Mitchell et al. (2007), wherein internal risk management causes market players to reduce their participation to the market. We consider a form of ‘‘external’’ risk management imposed by the option exchanges: margin requirements.

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