Margin Requirements and Equity Option Returns*

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Abstract

In equity option markets, traders face margin requirements both for the options themselves and for hedging-related positions in the underlying stock market. We show that these requirements carry a significant *margin premium* in the cross-section of equity option returns. The sign of the margin premium depends on demand pressure: If end-users are on the long side of the market, option returns decrease with margins, while they increase otherwise. Our results are statistically and economically significant and robust to different margin specifications and various control variables. We explain our findings by a model of funding-constrained derivatives dealers that require compensation for satisfying end-users' option demand.

Keywords: equity options, margins, funding liquidity, cross-section of option returns
JEL Classification: G12, G13

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1 Introduction

Recent research shows that margin requirements are an important determinant of prices in asset and derivative markets (e.g., Santa-Clara and Saretto, 2009; Gârleanu and Pedersen, 2011; Rytchkov, 2014). While some popular phenomena, such as the negative CDS-bond basis during the financial crisis, highlight the empirical relevance of margin-related funding effects, evidence on the general role of margin requirements in derivatives markets is relatively limited. An important yet open question is whether margin requirements matter for the returns on stock options. In this paper, we show that the cross-section of equity option returns contains an economically and statistically significant premium that compensates for margin requirements in the options market and in the underlying stock market.

Our analysis is guided by a model for derivatives markets, in which option dealers face an exogenous demand of end-users, hedge their position in the underlying stock, and comply with margin requirements set by regulators. Margin requirements for the option and the stock position tie up the dealer's capital and are compensated by the market if funding is costly. This gives rise to a *margin premium* which is priced in the cross-section of equity options. For a particular option, the magnitude of the margin premium depends on the option's margin requirement and the capital requirement for the hedging-related stock position, both relative to the option's price. The sign of the margin premium depends on end-user demand being positive or negative, with higher margin requirements leading to higher option returns if the dealer takes the long side of the market but lower returns when the dealer is short. Furthermore, margin premia are larger when funding is scarce and funding costs are high.

We investigate the model predictions for a large sample of U.S. equity options, based on margin rules that are applied in practice.[1] In particular, the margin for shorting an option depends on the price of the underlying and the option's moneyness, while entering a long position involves depositing a fixed fraction of the option price. For the underlying stock market, the margin requirement is a fixed fraction of the stock price for all stocks, such that the cross-sectional variation of required hedging capital comes from the size of the hedging-related stock position. Our model implies that the compensation for these margin requirements through margin premia depends on the demand of end-users or equivalently on the expensiveness of options, which is confirmed by our empirical analysis.[2] A naive univariate sort of delta-hedged option returns by margin requirements yields a negative margin premium, which vanishes after the inclusion of standard risk factors. On the other hand, we find highly significant, robust margin premia once we condition on the expensiveness of options (our proxy for demand pressure). In particular, a strategy that is long in call (put) options with low margin requirements and short in options with high margin requirements yields a monthly delta-hedged excess return of 12% (3%) if we restrict our sample on options with high *buying* pressure. The opposite strategy, buying options with high margins and selling low-margin options, makes 2% (2%) per month for options with high *selling* pressure.

These results match the predictions of our model and indicate that margin premia play an important role for the cross-section of option returns. To strengthen our argument further, we rule out several alternative explanations for these results. First, our findings hold both for call and for put options and are therefore not driven by one of the many effects that are specific to puts. Second, we argue that margin premia are different from the "embedded

[1] For options, we rely on the margin requirements specified by the CBOE margin manual. Minimum margin requirements on stock positions are defined in Federal Reserve Board's Regulation T.

[2] It would not be necessary to condition on end-user demand or equivalently on expensiveness if end-users were consistently short (or long) in all options and at all points in time. Empirical evidence on actual order imbalance reported by Goyenko (2015), however, suggests that this is not the case.

leverage" effect proposed by Frazzini and Pedersen (2012), even though the hedging capital requirement in our model is proportional to the embedded leverage of an option. Frazzini and Pedersen (2012) suggest that options with higher embedded leverage have smaller returns due to higher end-user demand for these options. Since we condition on demand pressure in the empirical analysis, our results are not driven by demand effects. Moreover, we find that the returns of options that are subject to end-user *selling* pressure *increase* with the hedging capital requirement, which contrasts the negative premia on embedded leverage found by Frazzini and Pedersen (2012).

Third, we confirm our results by running Fama-MacBeth regressions of option returns on margin requirements, controlling for a number of additional effects that could potentially bias our results. In particular, we control for moneyness and maturity effects, option greeks as determinants of hedging costs (Gârleanu, Pedersen and Poteshman, 2009), liquidity effects (Christoffersen et al., 2015), systematic risk (Duan and Wei, 2009), as well as the underlying stock's volatility (Cao and Han, 2013) and the firm size and leverage. To condition on the demand pressure of an option, we allow the slope coefficient on margin requirements to differ across demand pressure quantiles. The results of the regressions confirm those of the portfolio sorts, yielding a significantly negative margin coefficient for high-demand options and a significantly positive estimate in the low-demand quantiles. In addition, the regressions allow us to separate the effects of the options-related margin and the stock-related margin.

Finally, our analyses show that margin premia are higher when funding liquidity is scarce. Based on the model's prediction, we construct a measure of funding liquidity from the time series of margin-sorted long-short portfolio returns. We find that this measure is significantly correlated with the TED spread and Broker-Dealer leverage, thereby providing support for the notion that margin requirements affect option returns through the funding channel.

Our paper contributes to a fast-growing literature that emphasizes the role of financial intermediaries for security prices (He and Krishnamurthy, 2012, 2013). The idea of this literature is that financial intermediaries – who are often the marginal investors in asset or derivatives markets – need to be compensated for bearing risk or providing liquidity if their capacities for doing so are limited. In this spirit, several papers show that margins and capital requirements are an important factor for asset prices (Asness, Frazzini and Pedersen, 2012; Adrian, Etula and Muir, 2014; Frazzini and Pedersen, 2014; Rytchkov, 2014) and derivatives (Santa-Clara and Saretto, 2009; Gârleanu and Pedersen, 2011) if agents are funding-constrained. A particularity of derivatives markets is that the intermediaries, e.g., option dealers, hedge their positions in the underlying market, such that their compensation is also driven by the costs of the hedging strategy and the amount of unhedgeable risks (see Gârleanu, Pedersen and Poteshman, 2009; Engle and Neri, 2010; Kanne, Korn and Uhrig-Homburg, 2015; Leippold and Su, 2015; Muravyev, 2016).[3] In the equity options market, both the margin requirements for the options themselves and the capital tied up for the hedging strategy are relevant and priced in the cross-section of option returns, as we show in this paper.

Furthermore, several papers reveal that the effects described are more pronounced when funding liquidity is scarce (Chen and Lu, 2016; Golez, Jackwerth and Slavutskaya, 2016) and vary with the end-user demand (Bollen and Whaley, 2004; Gârleanu, Pedersen and Poteshman, 2009; Frazzini and Pedersen, 2012; Boyer and Vorkink, 2014; Constantinides and Lian, 2015). We show that both aspects are also important for the margin premium in the equity options market: In our case, the sign of the margin premium depends on whether the

[3] Related, margin requirements in option markets may matter for the microstructure of the options and underlying stock markets; e.g. Mayhew, Sarin and Shastri (1995) find that changes in option margin requirements affect bid-ask spreads in both markets. They also argue that associated changes in transaction costs may affect in which markets uninformed investors prefer to trade.

end-user demand is negative or positive, making option dealers take the long or the short side of the market. The magnitude of this (positive or negative) premium depends on the available funding liquidity, and we find larger margin premia when funding is scarce.

Finally, our study naturally contributes to the literature on the cross-section of option returns in general. In this literature, it is shown that the cross-section of option returns can partly be explained by volatility risk (Coval and Shumway, 2001; Bakshi and Kapadia, 2003; Schürhoff and Ziegler, 2011), jump risk (Broadie, Chernov and Johannes, 2009), correlation risk (Driessen, Maenhout and Vilkov, 2009), and systematic risk in general (Duan and Wei, 2009), as well as by option expensiveness (Goyal and Saretto, 2009), idiosyncratic stock volatility (Cao and Han, 2013), and firm characteristics (Cao et al., 2017). Recent works reveal that the options' market liquidity (Christoffersen et al., 2015) and related liquidity risk (Choy and Wei, 2016) is priced in the cross-section as well, suggesting that liquidity considerations play an important role for option dealers. Our analysis confirms this intuition from the funding liquidity perspective, showing that margin requirements are an important driver of the cross-section of option returns.

The rest of this paper is structured follows. In Section 2, we develop a model for derivatives markets that allows us to make several predictions on the effect of margin requirements on equity option returns. Section 3 describes our options sample as well as the margin rules and the measure for end-user option demand. Section 4 analyzes the returns of option portfolios that are constructed by sorting our option sample with respect to margin requirements. In Section 5, we extend our analysis of margin premia by running Fama-MacBeth regressions and controlling for several variables that drive the cross-section of option returns. We construct an option-market implied measure for funding liquidity based on margin premia in Section 6. Section 7 confirms the robustness of our results, and Section 8 concludes the paper.

2 Option Trading under Funding Constraints

We develop a model for derivatives markets that accounts for two main market features: margin requirements for derivatives and the underlying stock market, and limited funding capacities of derivatives traders. In the model, option dealers face an exogenous option demand of end-users and are compensated by a premium for the costs incurred to satisfy this demand, similar to Gârleanu, Pedersen and Poteshman (2009). In our case, these costs arise from margin requirements in the option market and the underlying stock market – margins tie up capital, which is costly when funding is limited (see Gârleanu and Pedersen, 2011). Combining these features, the model allows us to characterize the effect of margin requirements on option returns theoretically, guiding our empirical analysis.

2.1 Model

Instruments and Payoffs We consider a simple discrete-time economy with a risk-free asset paying an exogenous rate $R^f = 1 + r^f$, and a risky asset with exogenous price S_t, which we call *stock*. In addition, there is a derivative security with endogenous price F_t, called *option*. Let $\bar{\mu}_S = \mathrm{E}_t(S_{t+1} - R^f S_t)$ and $\bar{\mu}_F = \mathrm{E}_t(F_{t+1} - R^f F_t)$ denote the expected excess gains of an investment in the stock and the option, respectively. Furthermore, we denote the conditional variances and covariances of prices as $\sigma_S^2 = \mathrm{var}_t(S_{t+1})$, $\sigma_F^2 = \mathrm{var}_t(F_{t+1})$, and $\sigma_{SF} = \mathrm{cov}_t(S_{t+1}, F_{t+1})$.

Agents Following Frazzini and Pedersen (2014), we consider an overlapping-generations model with agents living for two periods. In time t, the economy is populated by two young agents: a derivatives *end-user* who has an exogenous, inelastic option demand d, and a derivatives *dealer* with zero wealth, $W_t = 0$, who satisfies the end-user demand and hedges herself through the stock market. The dealer maximizes expected utility of next period's wealth by choosing optimal positions $x = x_t$ and $q = q_t$ in the stock and the option market:

$$\max_{x,q} \mathrm{E}_t(W_{t+1}) - \frac{\gamma}{2} \mathrm{var}_t(W_{t+1}), \tag{1}$$

where $\gamma > 0$ characterizes the dealer's risk aversion.

As a benchmark case, let us consider the standard portfolio choice problem of an unconstrained dealer, assuming an end-user option demand of zero. In that case, the dealer takes no position in the option market by assumption and her terminal wealth is given by $W_{t+1} = x(S_{t+1} - R^f S_t)$. This yields the well-known solution $x^* = \frac{\bar{\mu}_S}{\gamma \sigma_S^2} =: \eta$.

Margin Requirements We now introduce margin requirements into our setting. Specifically, for a position $q > 0$ in the option market, a net margin of $M_F^+ \geq 0$ has to be held in the margin account, while the short margin for $q < 0$ is $M_F^- \geq 0$. For the stock market, we assume that the dealer holds an ex-ante optimal stock position of η without incurring funding costs,[4] and has to post a margin $M_S \geq 0$ for her *excess* stock holding $\theta = x - \eta$.[5]

Altogether, for a portfolio of $\eta + \theta$ stocks and q options, a net margin of

$$M(\theta, q) = |\theta|\, M_S + |q| \left(\mathbf{1}_{\{q>0\}} M_F^+ + \mathbf{1}_{\{q<0\}} M_F^- \right) \tag{2}$$

[4] In practice, for an institutional option trader, this position may be held by the stock trading desk. Consequently, its funding costs are not relevant for the optimization problem of the dealer.

[5] If one buys a stock, one may use a margin loan of up to $S_t - M_S$. The remainder has to be financed with own capital. On the other hand, a short position demands the deposit of $S_t + M_S$, which may be covered in part by the short sale proceeds S_t. In either case, the net capital requirement is M_S.

has to be held in the margin account, earning the risk-free rate. Most importantly, Eq. (2) implies that the margin requirement of a security is independent of the remaining portfolio composition (as also assumed by Gârleanu and Pedersen, 2011, for example).

Funding Finally, we assume that the dealer finances the margins by obtaining funding at an individual rate $\tilde{r} \geq r^f$, and we define $\psi = \tilde{r} - r^f$ as the dealer's funding spread.[6] If $\tilde{r} > r^f$, we say that the dealer is funding-constrained.

Under these assumptions, the wealth of a dealer who holds a portfolio of $\eta + \theta$ stocks and q options evolves according to the following dynamics:

$$W_{t+1} = (\eta + \theta)(S_{t+1} - R^f S_t) + q(F_{t+1} - R^f F_t) - \psi \left(|\theta| \, M_S + |q| \left(\mathbf{1}_{\{q>0\}} M_F^+ + \mathbf{1}_{\{q<0\}} M_F^- \right) \right). \tag{3}$$

By assumption, the dealer satisfies any option demand d in equilibrium. The dealer hedges the associated risk with an additional stock position θ, provided that the end-user's option demand, dealer's risk aversion, and the covariance between stock and option prices are sufficiently large, so that the utility gain from risk reduction is larger than the marginal funding costs of the hedging position in the stock:

Proposition 1 (Hedging)**.** *If there is a non-zero option demand d with $|d\gamma\sigma_{SF}| > \psi M_S$, the dealer hedges herself through an additional position of*

$$\theta = d\Delta - \operatorname{sgn}(d\Delta) \frac{\psi}{\gamma \sigma_S^2} M_S \tag{4}$$

[6] Alternatively, as outlined in Gârleanu and Pedersen (2011), ψ could also be interpreted as shadow costs of funding arising from binding capital constraints.

stocks, where $\Delta = \frac{\sigma_{SF}}{\sigma_S^2}$.

Note that Δ is a discrete-time version of the option's delta, such that the dealer implements a standard delta-hedge, adjusted for the margin that is required for the stock position.

In equilibrium, the current option price F_t establishes in such way that it is, in fact, optimal for the dealer to satisfy the demand and take an option position of $-d$.

Proposition 2 (Option Prices)**.** *Under the assumptions of Proposition 1, the equilibrium option price is given by*

$$F_t = F_t^0 + d\gamma \frac{\sigma_F^2 - \Delta\sigma_{SF}}{R^f} + \text{sgn}(d)\frac{\psi}{R^f}\left(M_F + |\Delta|\, M_S\right), \tag{5}$$

where $F_t^0 = \text{E}_t\left(\frac{F_{t+1} - \Delta\bar{\mu}_S}{R^f}\right)$ *is the option price in the unconstrained equilibrium without option demand* ($d = 0, \psi = 0$)*. Consequently, the sign of demand is related to the option's price through*

$$\text{sgn}(d) = \text{sgn}(F_t - F_t^0). \tag{6}$$

Intuitively, if there is option demand on the long side of the market, options are relatively expensive. This result serves as a motivation for our empirical analysis, where we use the difference of implied and historical volatilities as a measure of *price pressure* and, consequently, as an approximation for the sign of demand.

It is important to note that the resulting option prices could be negative in equilibrium when the end-user demand is negative and funding costs are extremely high, for example. In the subsequent simulation study, we show that this problem does not arise under reasonable specifications of the model parameters. Nevertheless, we make the following assumption:

Assumption 1. *The equilibrium option price is positive,* $F_t > 0$.

Proposition 2 also has a useful implication for option returns.

Proposition 3 (Option Returns). *If there is a non-zero option demand d with $|d\gamma\sigma_{SF}| > \psi M_S$, the expected option return is*

$$\mathrm{E}_t\left(\frac{F_{t+1}-F_t}{F_t}\right) = r^f + \frac{\Delta\bar{\mu}_S}{F_t} - d\gamma\frac{\sigma_F^2 - \Delta\sigma_{SF}}{F_t} - \operatorname{sgn}(d)\,\psi\,\frac{M_F + |\Delta|\,M_S}{F_t}, \tag{7}$$

where $M_F = M_F^{-\operatorname{sgn}(d)}$ is the option margin faced by the dealer, and $\operatorname{sgn}(d)$ is the sign of demand. Equivalently, delta-hedged excess option returns are given by

$$\mathrm{E}_t\left(\frac{G_{t,t+1}}{F_t}\right) = -d\gamma\frac{\sigma_F^2 - \Delta\sigma_{SF}}{F_t} - \operatorname{sgn}(d)\,\psi\,\frac{M_F + |\Delta|\,M_S}{F_t}, \tag{8}$$

where $G_{t,t+1} = F_{t+1} - R^f F_t - \Delta(S_{t+1} - R^f S_t)$ denotes the gains of a delta-hedged portfolio.

The first term of Eq. (8), $-d\gamma(\sigma_F^2 - \Delta\sigma_{SF})F_t^{-1}$, is an analogous result to Gârleanu, Pedersen and Poteshman (2009): Option returns decrease proportionally with demand, risk aversion of dealers, and the unhedgeable part of the option dynamics. In addition, delta-hedged option returns exhibit a twofold margin premium. In line with Gârleanu and Pedersen (2011), there is a compensation for costly margin requirements of the options, which is given by the product of the relative margin requirement, the funding spread, and an indicator for the position held. Furthermore, funding costs of the heding-related stock position in the underlying are compensated, as well. More precisely, option returns contain a premium for the *marginal* funding costs of the hedging position. Therefore, option returns compensate for $|\Delta|M_S$, although the option dealer optimally chooses not to hold a full delta-hedging position.

Overall, we define the second term of Eq. (8) as the *margin premium*

$$\pi = -\,\mathrm{sgn}(d)\,\psi\,\frac{M_F + |\Delta|\,M_S}{F_t}, \tag{9}$$

which depends on the margin requirement faced by the dealer, who might have a long or short option position, depending on the option demand.

In the following, we assume that margin loans on long option positions are not possible,[7] so that $M_F^+ = F$. Under this additional assumption, the margin premium takes the following form:

Corollary 1 (Margin Premium)**.** *If $M_F^+ = F_t$, the margin premium equals*

$$\pi = \begin{cases} -\psi\left(\frac{M_F^-}{F_t} + \frac{|\Delta| M_S}{F_t}\right), & F_t > F_t^0, \\ +\psi\left(1 + \frac{|\Delta| M_S}{F_t}\right), & F_t < F_t^0. \end{cases} \tag{10}$$

As before, the sign of the margin premium depends on the option demand, which can be inferred from price pressure. In absolute terms, the hedging position induces a premium $\psi|\Delta|\,M_S/F$, which is independent of option demand. On the contrary, even in absolute terms, the premium on option margin requirements still depends on the position of the dealer. If the dealer is short, the margin premium reflects the requirement on a short option position relative to the option's price, M_F^-/F. Otherwise, if the dealer has a long position, the relevant margin requirement is $M_F^+/F = 1$. Therefore, there is no cross-sectional variation in the premium on option margins if the dealer is long.

[7] Under the strategy-based margin rules of the CBOE, margin loans are only allowed for options with a time to maturity of more than nine months. For such options, the margin requirement is 75% of the options' price. So even if margin loans are allowed, there is no pronounced cross-sectional variation between different options in margin requirements relative to the options' prices.

In summary, margin requirements for short option positions, M_F^-/F, and the hedging-related stock position, $|\Delta|\, M_S/F$, both relative to the option's price, are of central importance for our analysis. In the following, we refer to these quantities simply as *option margin* m and *hedging capital* $\widetilde{m}$.

Altogether, we get several testable hypotheses:

Corollary 2. *Under the given assumptions, our model predicts that*

a) Option returns decrease in option margins and hedging capital requirements for options in which end-users are long.

b) Option returns increase in hedging capital requirements, but exhibit no cross-sectional variation with respect to option margins for options in which end-users are short.

c) The effects of option margins and hedging capital requirements are stronger when agents are more funding-constrained, i.e., for large ψ*.*

2.2 Model Simulation with Real-World Margin Requirements

In this section, we discuss the implications of our model for delta-hedged option returns when the funding-constrained dealer faces precisely the margin rules that we study in our empirical analysis below. We show how margin requirements amplify demand-based option pricing effects and, as a consequence, matter for delta-hedged option returns.

In our simulation, we study the pricing and the expected returns of call options with a maturity of six months.[8] We start by simulating 100,000 stock price paths on a fine grid from $t = 0$ to $T = 0.5$ years. The stock price S_t is governed by a diffusion process with stochastic

[8] Results for put options and other maturities are qualitatively similar and are available upon request.

volatility, closely following Broadie, Chernov and Johannes (2007) and Eraker, Johannes and Polson (2003); for details see Appendix B. In this setting, stochastic volatility constitutes an additional source of unhedgeable risk beyond discrete-time trading. With the initial stock price being $S_0 = 1$, a risk-free interest rate $r^f = 3\%$, and an equity premium of 5%, a dealer with risk-aversion $\gamma = 4$ chooses an optimal ex-ante position of $\eta = 0.56$ stocks.

The dealer satisfies a fixed, exogenous end-user demand d for call options, which determines her position in the option market as well as her hedging position in the stock market. For a short position in call options, she has to comply with the CBOE's margin requirement to post 20% of the underlying price reduced by the current out-of-the-money amount, but at least 10% of the underlying price, i.e.,

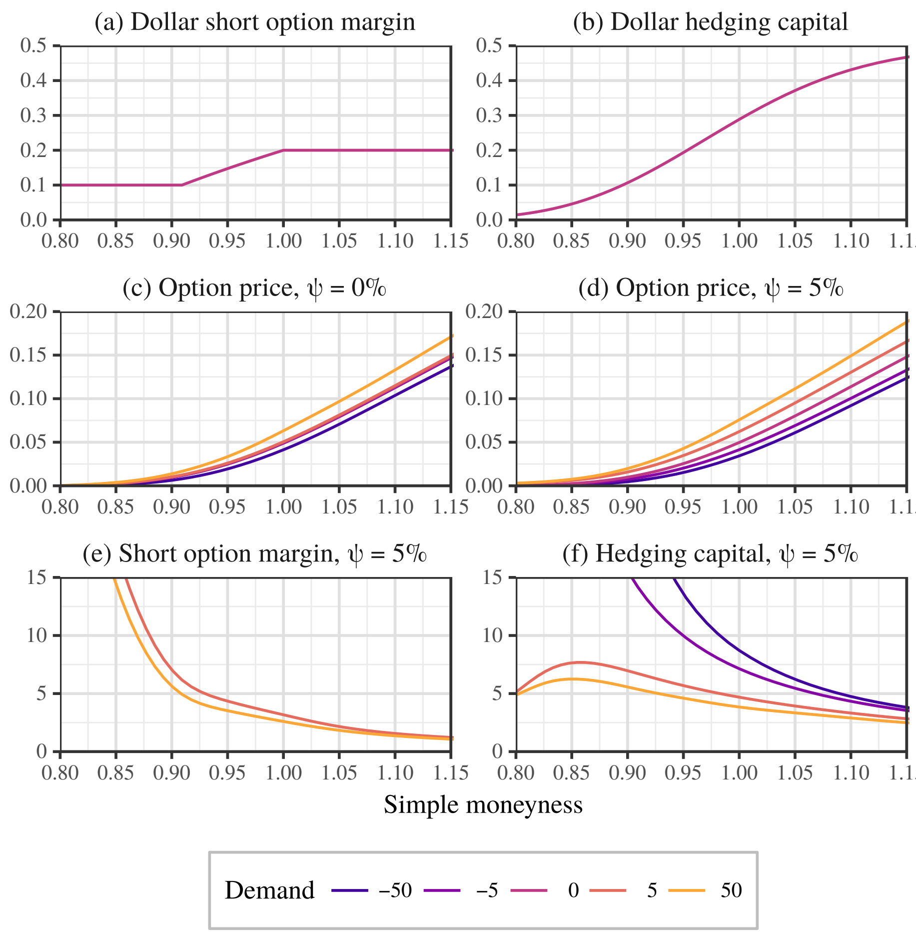
$$M_F^- = \max\left(0.2 \cdot S - (K - S)^+,\ 0.1 \cdot S\right),$$

where K is the option's strike price. Fig. 1 plots the dealer's dollar option margin across moneyness levels in Panel (a), illustrating that it is in the range from 10 cents for deep OTM options to 20 cents for ATM and ITM options. For a long position, the CBOE requires the payment of the option premium in full, such that no additional margin requirement is needed. In the stock market, the dealer has to comply with the Federal Reserve Board's Regulation T that the initial margin requirement has to be at least 50%, i.e., for each stock held long or short in her portfolio, she has to post $M_S = 0.5 \times S$. Panel (b) of Fig. 1 shows how the dollar hedging capital increases with the moneyness of the call option (because the size of the hedging position depends on the option's moneyness).[9]

[9] In line with our empirical analysis, we define hedging capital using the options' Black-Scholes delta, such that the dollar hedging capital is independent from the demand level. But the results do not change substantially when we define hedging capital in terms of the model-implied deltas.

Figure 1: Simulation results: Margin requirements and option prices

This figure visualizes margin requirements and prices of the simulated options. Panel (a) and (b) show the dollar margin required for a short option and the associated hedging capital. Panel (c) and (d) visualize option prices for a funding spread of zero and five percent, respectively. Focussing on the latter case, panels (e) and (f) show margin requirements relative to the option prices.



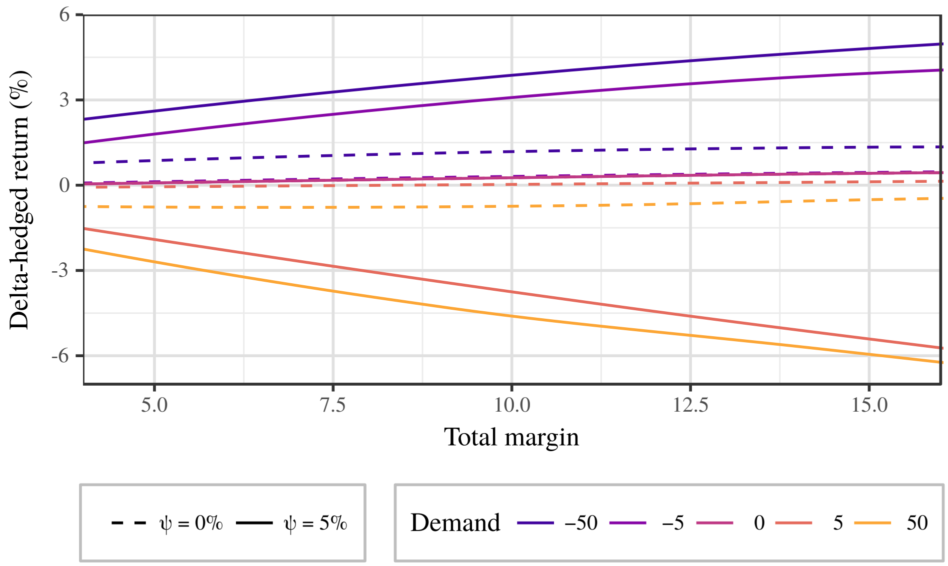
From Eq. (5) we know that both margin requirements affect the funding-constrained dealer's pricing of options. Starting with a dealer who is not funding-constrained, Panel (c) shows how call option prices increase with moneyness and with end-user demand. In this case, the price differences result solely from the premium on unhedgeable risk, in line with Gârleanu, Pedersen and Poteshman (2009). Panel (d) shows that the pricing of a constrained dealer subject to a funding spread $\psi = 5\%$ amplifies demand-effects on option prices. Using the option prices set by the funding constrained dealer (Panel (d)) and the dollar margins (Panels (a) and (b)), we compute the dealer's relative margin requirements. In the options market (Panel (e)), the dealer's margin requirement for short positions decreases in moneyness and option demand, which reflects that options with a given moneyness that are subject to higher demand are more expensive. On the other hand, there is no cross-sectional variation in option margin requirements when the dealer has a long position in options (to satisfy a negative end-user demand), because the initial premium has to be paid in full, i.e., the relative margin requirement is 100%. For hedging capital, we observe cross-sectional differences in both scenarios, but the patterns differ. Whereas hedging capital is monotonously decreasing in moneyness if the dealer is long, there is a hump-shaped relation between moneyness and hedging capital if the dealer holds a short position in options. This pattern is in line with the empirical data (cf. Fig. 7) and allows us to disentangle the effects of the two margin variables in our empirical analysis.

Eq. (8) tells us that the total margin requirement $(M_F + |\Delta|\, M_S)/F$ drives delta-hedged option returns, as we illustrate in Fig. 2. For options with positive end-user demand, i.e., options that are expensive, delta-hedged returns decrease with margin requirements. This negative margin premium reflects the compensation the funding-constrained dealer requires for being short in the options market. By contrast, for options with negative end-user demand, i.e., cheap options, there is a positive relation between delta-hedged returns and margin requirements. Fig. 2 also shows that delta-hedged option returns are smaller in magnitude and independent of margin capital when the dealer is not constrained.

In the next subsection, we discuss how we can test these return predictions of our model in the empirical data.

Figure 2: Simulation results: Delta-hedged returns

This figure visualizes the relation between total margin requirements, i.e., the sum of option margins and hedging capital, and delta-hedged returns of simulated options. The dashed lines show results for an unconstrained option dealer, the solid lines correspond to a funding spread of 5 percent.



2.3 Model Guidance for the Empirical Analysis

The model provides straight-forward predictions for how end-user demand, margin requirements, and funding constraints matter for the prices and returns of options. These model predictions suggest themselves to be tested in a portfolio double-sort setup: First sort options into portfolios based on end-user demand (to determine whether the dealer is long or short in the option), and second, within the demand portfolios, sort options based on the required margin capital. As illustrated in Fig. 2, we would expect to find positive margin premia for options with low end-user demand and negative margin premia for options with high end-user demand. While these model predictions are straight-forward, the empirical challenge arises from the fact that we cannot directly observe end-user demand and dealers' margin capital. In this section, we discuss how the insights provided by our model allow us to cope with these challenges and to empirically test the predictions of our model using observable quantities. We extend the simulation study and present results of portfolio double-sorts using the proxies available for the empirical analysis and show how these results compare to using the quantities that they proxy for (known to us in the simulated world). We also discuss how our model gives rise and relates to stylized facts documented in empirical studies, such as the negative returns to buying expensive and selling cheap options and the inverse relation between returns and embedded leverage.

To alleviate the problem that we cannot observe end-user demand, we rely on the prediction of our model that option expensiveness is directly related to end-user demand: options are expensive (cheap) when there is high (low) end-user demand. Gârleanu, Pedersen and Poteshman (2009) provide empirical evidence for such a relation and we use the expensiveness measure they propose as a proxy for end-user demand pressure in the simulation study as well as for most of our empirical analysis.[10] We analyze our model predictions and the empirical challenges in an extended sample of 10 000 simulated call options with randomly chosen characteristics. Specifically, for each option, we independently draw a moneyness between 0.9 and 1.1, a time to maturity between 2 and 12 months, and an end-user demand between −50 and +50. Then, we calculate the model-implied price, the expected delta-hedged return, as well as the option's expensiveness and margin requirements.[11]

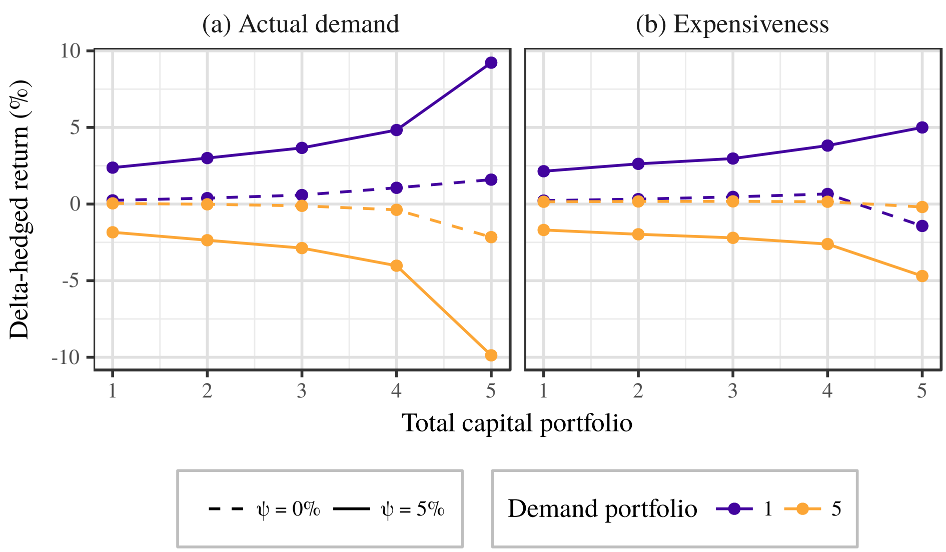
[10]In empirical robustness checks, we also construct demand proxies from volume data to show that demand and expensiveness are significantly related in the subsample in which we have data for both.

[11] The interaction between demand, margin requirements, and option prices results in an unrealistically strong link between expensiveness and the proposed margin variables. While the return patterns for very cheap and very expensive options are virtually unaffected by this peculiarity, portfolio returns with expensiveness close to zero become noisy and large in absolute terms. To alleviate this problem, we add a small random measurement error to the estimated expensiveness, which dampens the correlation to the margin proxies while the tight connection to end-user demand remains.

Panel (a) of Fig. 3 shows average delta-hedged returns from a double sort on end-user demand and total margin requirements based on these simulated options. In line with our intuition, margin portfolio returns are increasing when demand is small (i.e., negative) and decreasing when demand is large. We find a similar, albeit much smaller effect in the case of unconstrained dealers as well. This finding implies that the margin portfolio sort may pick up some cross-sectional variation in unhedgeable risk that was not present in the previously analyzed sample with a fixed time to maturity. Interestingly, results from a portfolio sorts on margins conditional on expensiveness are different: While the return patterns for the case of costly funding are qualitatively similar, there is no more evidence for a premium on unhedgeable risk.

Figure 3: Average returns of simulated demand-margin portfolios

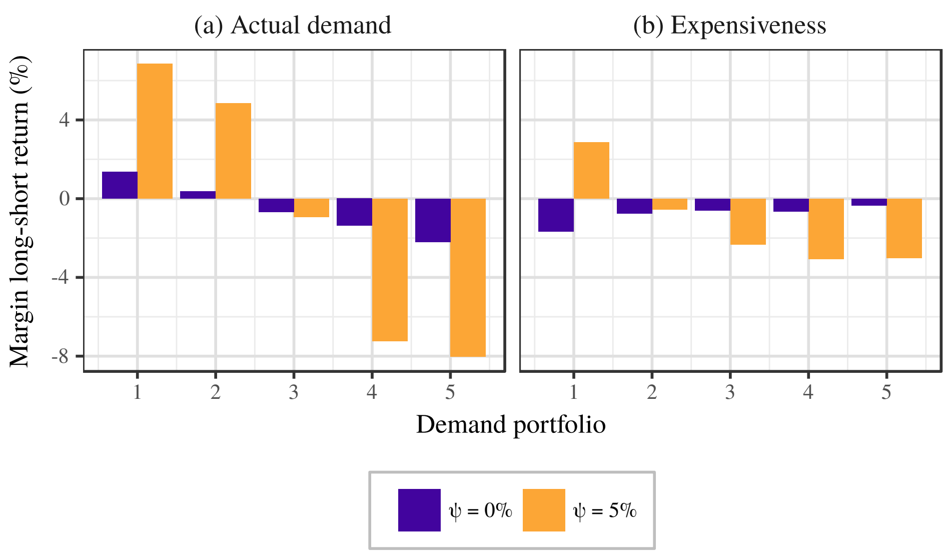
This figure shows average returns of double-sorted portfolios formed on different demand measures and the total margin requirement. First, we form quintile portfolios on the actual demand and options' expensiveness, respectively. Within each of these portfolios, we form quintile portfolios on total margins. The solid lines and dashed lines show average returns of these second-stage portfolios within the first and fifth quintile of the respective demand measure for a funding spread of zero and five percent, respectively.



In addition, Fig. 4 visualizes margin long-short returns within all quintiles formed on actual demand and expensiveness, respectively. Overall, returns are decreasing in the level of the chosen demand proxy, in line with our intuition. If we condition on the actual demand, the pattern is almost staircase-shaped, reflecting that the margin premium does not directly depend on the level, but on the sign of demand. Using expensiveness as demand proxy, returns are still monotonously decreasing, but in a more continuous way. In addition, although demand is by construction symmetric around zero in this sample, all but the first long-short portfolio have a negative average return. These findings match the empirical patterns remarkably well, as reported in Section 4.

Figure 4: Simulated margin long-short returns conditional on different demand measures

This figure shows average long-short returns of total margin portfolios conditional on actual demand and expensiveness, respectively. First, we form quintile portfolios on the respective demand measure, and then conditional quintile portfolios on the total margin requirements. The bars show the resulting long-short return given by the difference between the highest and lowest margin quintile returns.



It is also interesting to note that the expensiveness-related return implications of our model match the empirical results of Goyal and Saretto (2009). More specifically, Fig. 3(b) shows that expensive options always earn lower delta-hedged returns than cheap options when the dealer is funding-constrained. Goyal and Saretto (2009) document a very similar pattern in delta-hedged call returns and conclude that its source is unclear.[12] Our results suggests that this return pattern arises from constrained dealers requiring compensation for funding costs associated with margin requirements.

The second challenge for our empirical analysis is that we cannot directly observe dealer's margin capital. More specifically, we cannot know whether all dealers follow the hedging strategy that is optimal for the dealer in our model, i.e., to complement any option position with a delta-hedge in the stock market. In other words, in practice the total margin an option dealer has to post might not be strictly the sum of the option margin and the hedging capital but depends on her overall portfolio of stocks and options on a particular firm. In our empirical analysis, we follow two strategies to address this problem. First, we will separately study the effects of option margins and stock margins on delta-hedged excess returns. Second, as a robustness check, we will study portfolio margining of hypothetical portfolios.

The idea behind separating option margins and hedging capital is to study (relatively extreme) benchmark scenarios, such that (combinations of) these cover any plausible realistic cases. On the one hand, if a dealer does not hedge at all, she only has a position in the options market and margin premia exclusively arise from funding the required margin capital in the option market. On the other hand, if a dealer fully covers her options position with stocks, no option margin is needed and margin premia arise only from funding the hedging capital required in the stock market. Otherwise, when dealers partly hedge their options positions

[12] More precisely, Goyal and Saretto (2009) document high abnormal delta-hedged returns for options with a large difference between historical and implied volatility.

(e.g., with a delta-hedge, like in our model), we should find margin premia for the stock position to arise from the hedging capital as well as from option margins required for the remaining, uncovered option position.

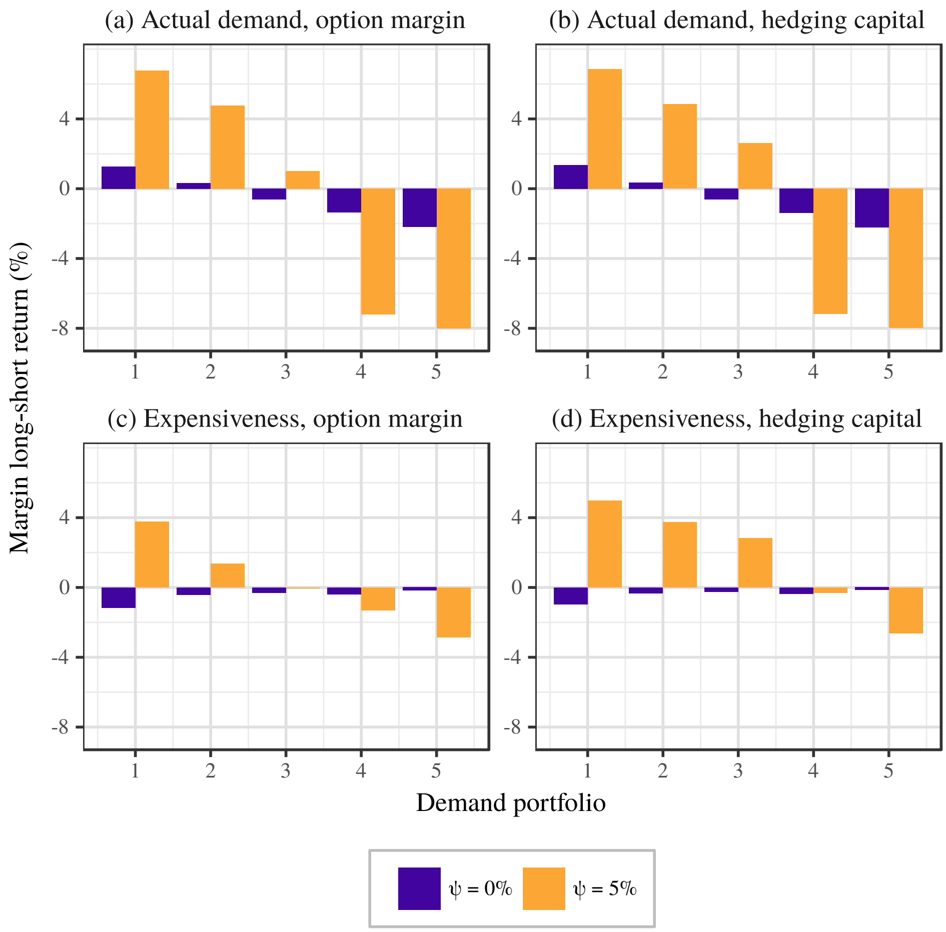
Moreover, there is no cross-sectional variation in option margin requirements when end-user demand is negative, i.e., when the dealer is long in the option. Given that the objective of our paper is to understand the cross-section of option returns, we focus on margins for short positions in the options market. For these option margins, we expect to find negative margin premia for options that are in high end-user demand, or equivalently, for options that are expensive. Conceptually, we would expect no relation for options in low demand (cheap options) but in the empirical portfolio double-sort setup, we may still find positive margin premia for cheap options due to the correlation between option margin requirements for short positions and hedging capital.[13] We illustrate this in more detail in the empirical analysis where we also control for such effects by complementing the portfolio sorts with cross-sectional regressions and indeed find that the option margin, controlling for hedging capital, only carries a negative premium for expensive options.

Fig. 5 summarizes the results from double sorts on demand and these margin variables in our simulated sample. For both margin variables, we find a decreasing return pattern, consistent with the finding for total margins (as shown in Fig. 4). In addition, results for portfolios formed conditional on expensiveness are again qualitatively similar to the findings based on the actual demand. These findings lead us to the conclusion that the chosen proxies for demand and margin requirements are closely linked to their true, unobservable counterparts, justifying the chosen approach for the subsequent empirical analysis.

[13] Sorting based on the short option margin requirement will result in similar portfolio allocations as the sorting based on hedging capital due to the correlation of the two sort variables, which arises from both being driven by the moneyness of the option.

Figure 5: Simulation long-short returns w.r.t option margins and hedging capital

This figure visualizes long-short returns of conditional portfolios formed on different proxies for demand and margin requirements. First, we form quintile portfolios on actual demand and expensiveness, respectively. Then, within these portfolios, we form portfolios on either option margins or hedging capital. The blue and yellow bars show the return difference between the highest and lowest margin quintile for a funding spread of zero and five percent, respectively.



Our results for hedging capital can also be related to Frazzini and Pedersen (2012) who argue for an inverse relation between delta-hedged option returns and options' embedded leverage. Their measure of embedded leverage is proportional to the dealer's hedging capital.[14] While

[14] Frazzini and Pedersen (2012) define embedded leverage as $\Omega = |\Delta S/F|$. Since we assume a fixed margin requirement of 50% per share, their measure is indeed proportional to hedging capital: $\widetilde{m} = 0.5 \times \Omega$.

we treat demand as exogenous in our model, a positive end-user demand for options with high embedded leverage would make these options more expensive and lead dealers to demand a negative premium for the hedging capital, or equivalently embedded leverage. In other words, in a world that is populated by dealers that behave like in our model, and end-user demand being driven by demand for embedded leverage, one should find return patterns as in Frazzini and Pedersen (2012) – unconditionally. Conditional on expensiveness, however, margin premia or equivalently returns to embedded leverage can be negative or positive. In our empirical analysis, we indeed find unconditionally negative returns but that the sign of returns changes with expensiveness, consistent with the predictions of our model.

The above results guide our empirical analysis to study margin premia for option margins and hedging capital conditional on option expensiveness as a proxy for demand pressure.

3 Data and Methodology

Our analysis builds on options data from February 1996 to August 2013 provided by the OptionMetrics Ivy DB database. We restrict our sample to options on common stocks with standard settlement and expiration dates. Further, we remove option-date observations with missing prices or probable recording errors, that is, options with non-positive bid price or a bid-ask spread lower than the minimum tick size.[15] All prices are corrected for corporate actions using the adjustment factors provided by OptionMetrics. We use the U.S. Treasury Bills rate as the risk-free interest rate, which we obtain from Kenneth French's data library,[16] along with standard equity risk factors.

[15] For stocks that are part of the penny-pilot program, the minimum tick size is \$0.05 (\$0.01) for options trading above (below) \$3. For all other stocks, the minimum tick size is \$0.10 (\$0.05).

[16] `http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html`

For the calculation of delta-hedged option returns below, we define monthly holding periods (simply referred to as *month*) and apply additional filters to the first trading day of a month, in line with the literature (see Goyal and Saretto, 2009; Driessen, Maenhout and Vilkov, 2009, among others). Specifically, we drop options with zero open interest and missing implied volatility or delta. We remove options that violate standard no-arbitrage bounds. To minimize the impact of early exercise, we only keep options with a time value of at least 5% of the option value.[17] Finally, we exclude deep-out-of-the-money puts (i.e., with delta larger than -0.2), because these act as insurance against crises and are therefore likely subject to different demand and price pressures than the remaining option sample. In addition, their outlying high returns during periods of market distress makes inference about margin premia more imprecise. The results of this paper are robust to modifications of these selection criteria, as we discuss in Section 7.

Our full option sample consists of 6 058 466 option-months for calls and 3 687 177 for puts, summing up to 9 745 643 data points in total. Panel A of Table 1 shows more details on the composition of our sample. On average, we consider 204 398 options written on 2 416 stocks per year, or 22 options per stock and month.

3.1 Delta-Hedged Option Returns

Following Frazzini and Pedersen (2012), we use monthly delta-hedged option returns for our analysis. Our monthly holding periods are aligned at the expiration days of standard exchange-listed options, which is the Saturday following the third Friday of a given month. That is, we set up our portfolios at the first trading day after an expiration date (usually

[17] We define the time value of a call option as $F - \max(S - K, 0)$, and for a put option as $F - \max(K - S, 0)$, where F is the option's price, K is the strike price, and S is the price of the underlying stock.

Table 1: Descriptive statistics

This table shows several descriptive statistics on the sample of all equity options excludig deep-out-of-the-money puts. Panel A informs about the sample composition. For the first line, we count all available stocks within a year and calculate the mean, median, and standard deviation over all full years in our sample, i.e., from 1997 to 2012. In addition, quantiles at the 5% and 95% level are given in the last two columns. Lines (2) to (4) show the respective results for all options, as well as separately for call and put options. Lines (5) to (7) show the number of options per stock and months, using data from February 1996 up to August 2013. Panels B and C show summary statistics on delta-hedged option returns and our main explanatory variables, respectively.

Panel A: Sample composition

		Mean	Median	Std	5%	95%
(1)	Stocks per year	2 416	2 387	453	1 592	3 061
(2)	Options per year	204 398	184 256	67 906	101 411	317 871
(3)	Call options per year	119 485	110 473	37 773	61 442	180 095
(4)	Put options per year	84 913	73 783	30 331	39 969	137 776
(5)	Options per stock-month	22	14	25	2	68
(6)	Call options per stock-month	14	9	16	2	43
(7)	Put options per stock-month	9	6	9	1	27

Panel B: Delta-hedged option returns (monthly percent)

		Mean	Median	Std	Skewness	Kurtosis
(11)	Call option returns	−1.657	−0.788	26.698	−0.009	5.625
(12)	Put option returns	0.011	−0.422	14.624	0.227	3.434

Panel C: Explanatory variables

		Mean	Median	Std	5%	95%
(11)	Expensiveness	−0.023	−0.013	0.262	−0.455	0.373
(12)	Hedging capital	3.274	2.512	2.666	0.825	8.315
(13)	Option margin	4.001	1.619	14.605	0.453	12.984

a Monday) and unwind positions at the last trading day before the next expiration date (usually a Friday).

At portfolio formation, say in $t = 0$, we invest \$1 in an option and set up a self-financing hedging position in the underlying stock. The portfolio value at a later date can then be determined with the following iteration rule:

$$V_{t+1} = V_t + x\left(F_{t+1} - F_t\right) - x\Delta_t\left(S_{t+1} + D_{t+1} - S_t\right) + r_t^f\left(V_t - xF_t + x\Delta_t S_t\right), \tag{11}$$

where $x = \frac{1}{F_0}$ is the number of options in the portfolio and D_{t+1} is the dividend paid in $t+1$. We rebalance the hedging position in the stock each day, as long as delta is not missing. Otherwise, we hold the previous stock position until a new value for delta is available.

Finally, at the end of the month, i.e., at $t = T$, the portfolio has the value V_T. As $V_0 = 1$, the corresponding excess return is then given by

$$r_T = V_T - \prod_{t=0}^{T-1}(1 + r_t^f). \tag{12}$$

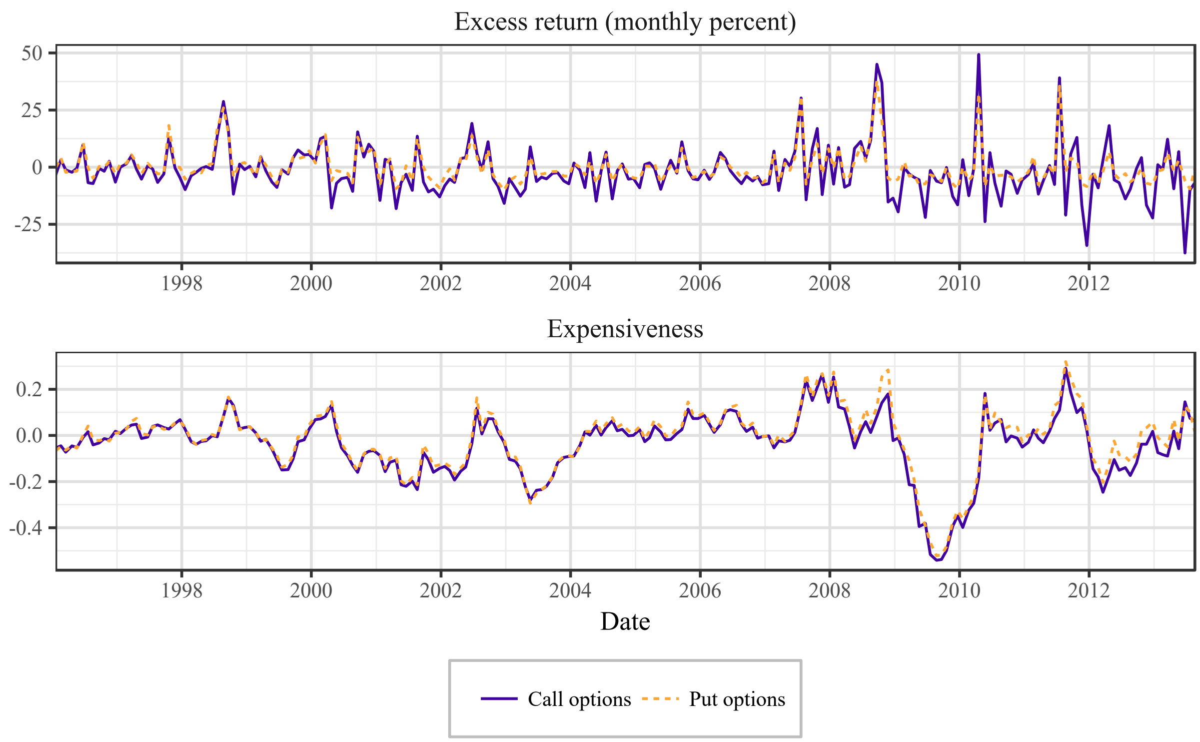
Panel B of Table 1 presents summary statistics and Fig. 6 shows the average delta-hedged call and put returns over time.

3.2 Margin Rules

We calculate margin requirements for the different options in our sample in line with the rules and regulations applied in practice. As becomes clear from our model, the margin related to an option position does not only include the option margin itself, but also the capital requirement for the underlying stock position that is entered for hedging purposes.

Figure 6: Monthly averages of excess returns and expensiveness

This figure shows means of monthly excess returns and expensiveness of call and put options. Returns are trimmed at the 1% level.



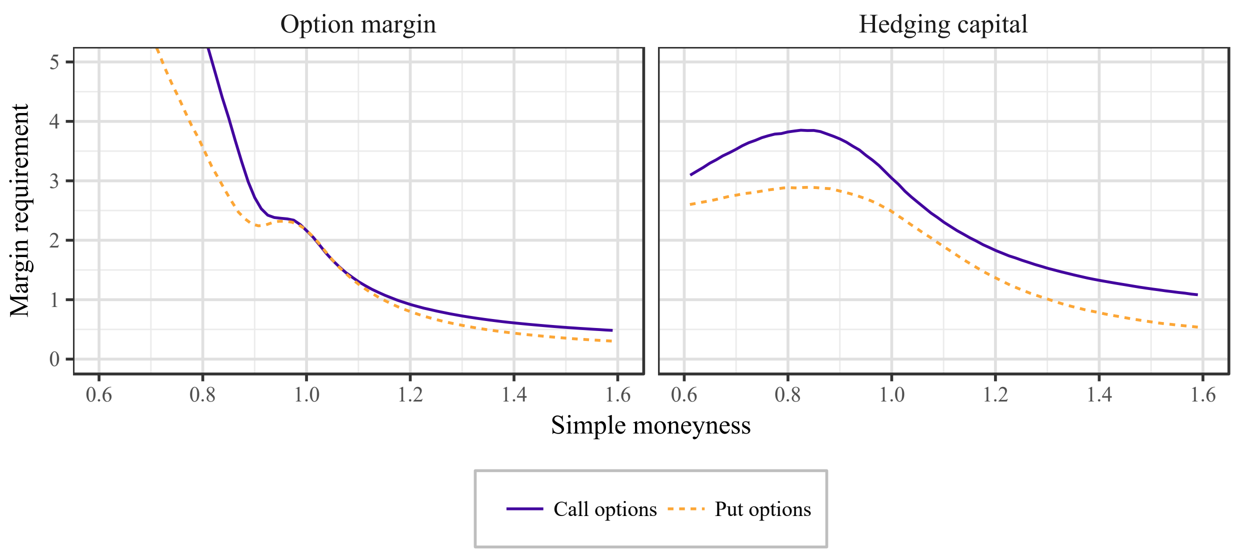
For the options position, we define margins based on the CBOE margins manual. Although margins can be set individually by each exchange, in practice all major option exchanges follow the margin requirements defined by the CBOE.[18] For a long position in a call or put option, the CBOE requires the payment of the option premium in full, such that no additional margin requirement is needed.[19] For a (naked) short position in equity options, on the other hand, the margin rule is more sophisticated: Investors are required to post 20%

[18] The rules at CBOE and NYSE agree on margin requirements of option positions. Other option exchanges (specifically PHLX, NOM, ISE) explicitly demand margin requirements according to CBOE or NYSE margin rules.

[19] For options with a time to maturity of more than 9 months, the margin requirement amounts to 75% of the options' price.

Figure 7: Cross-sectional variation of margin requirements

This figure visualizes the empirical relation between simple moneyness and margins requirements of call and put options. Specifically, we restrict our sample to options with 6 months to maturity and calculate average margin requirements for equally spaced moneyness bins.



of the underlying price reduced by the current out-of-the-money amount, but at least 10% of the underlying price for call options, and 10% of the strike price for put options. More formally, the margin is defined as

$$
\begin{aligned}
\text{Call: } M_F^- &= \max\left(0.2 \cdot S - (K - S)^+, 0.1 \cdot S\right), \\
\text{Put: } M_F^- &= \max\left(0.2 \cdot S - (S - K)^+, 0.1 \cdot K\right),
\end{aligned}
\tag{13}
$$

where K is the option's strike price. Fig. 7 illustrates the short margin requirements for call and put options dependent on the option's simple moneyness, i.e., S/K for calls and K/S for puts. The option margin $m = M_F^-/F$ generally decreases in moneyness, but the relation is not completely monotonic.

For a position in the underlying stock, a fixed fraction of the stock price is typically required as a margin. This fraction may depend on several stock characteristics like the stock price volatility or market liquidity and can be set individually by each broker. But as stated in the Federal Reserve Board's Regulation T, the initial margin requirement has to be at least 50% of the stock's price for any new long or short position. Throughout our empirical analysis, we set the stock margin according to this minimal requirement: $M_S = 0.5 \times S$. Since the hedging capital, $\widetilde{m} = |\Delta|\, M_S/F$, depends on the delta and the price of the option, the overall margin for the stock position varies in the cross-section of options as well.

As visualized in Fig. 1(f), our model implies that hedging capital can be non-monotonic and bounded if demand is positive, with maximum value attained at a some moneyness between 0.8 and 0.9. The empirical data confirms this prediction remarkably well, as shown in Fig. 7: For both option types, we observe a hump-shaped relation between moneyness and hedging capital. In any case, this analysis confirms that there is a distinct cross-sectional heterogeneity in both option margins and hedging capital requirements, which allows the identification of margin premia that are not predominantly driven by moneyness effects.

It is important to note that in practice, the margin an option dealer has to post might not be strictly the sum of the option margin and the hedging capital, as the reduced risk due to hedging activities may result in alleviations of option margin requirements. For example, the CBOE margin manual requires no margin for fully covered options positions. Therefore, the option margin effectively would only apply to the part of the position that is not covered, while the stock margin has to be posted for the whole stock position. As a result, the relevant margin requirements depend on the specific portfolio of a given dealer and possible individual margin arrangements.

We account for this difficulty in our empirical analysis by investigating the effect of the (naked) option margin and the hedging capital separately. If dealers do not hedge their option positions through the stock market in the real world, only the option margin should have an effect. On the other hand, if some dealers are exempt from option margin requirements due to their hedging activities, their hedging capital requirements still induces a margin premium. Finally, if dealers actually behave as predicted by our model, then both types of margins have to be posted and should play a role for option returns.

3.3 Demand and Price Pressure

As the margin premium of option returns depends on the sign of end-user demand according to our model, we need to measure the demand pressure in an option for our empirical analysis. We choose the option's expensiveness, defined as the current implied volatility minus the underlying's historical volatility, as a suitable proxy for demand pressure, motivated by two reasons. First, the analysis of Gârleanu, Pedersen and Poteshman (2009) reveals that empirically, there is a strong relation between the *price pressure* of an option, as reflected by the expensiveness, and the corresponding demand pressure. We confirm this positive relation to demand pressure using signed trading volumes from the International Securities Exchange (ISE) Open/Close Trade profile, as detailed in Section 7. Second, Proposition 2 shows that also in our model, a specific option is expensive (relative to a benchmark price for zero demand) whenever the end-user demand for that option is positive, and vice versa.

More precisely, we define an option's expensiveness as the log difference between its implied volatility and the underlying stock's historical volatility, measured as the standard deviation of log returns over the preceding 365 days:[20]

$$expensiveness_{i,t} = \log\left(iv_{i,t}\right) - \log\left(hv_{i,(t-365):t}\right) \tag{14}$$

Note that by this definition, we use the historical volatility simply as reference point and make no assumptions on any "true" value of volatility. The time series of average expensiveness is visualized in Fig. 6.

4 Portfolio Sorts by Margin Requirements

We begin our analysis by sorting options based on their margin requirements. To this end, we first perform naive single sorts on the margin variables. Second, we consider a double sort, which sorts options based on their expensiveness first, before forming quintiles for the margin requirements within each expensiveness quintile. This procedure accounts for the prediction of our model that margin requirements influence option returns in different directions, depending on the sign of the demand pressure. For all our sorts, we rebalance the portfolios on the first day of each month, and we perform all sorts separately for calls and puts. We then calculate the value-weighted average excess return for each of the portfolios, where we define the corresponding weights as the value of total open interest at portfolio formation, in line with Frazzini and Pedersen (2012).

To begin with, we construct portfolios of call options sorted by their option margins and present the results in Table 2. In the first line, we show that a simple univariate sort, which does not account for different expensiveness levels, generates a negative return on a portfolio

[20] We use historical volatilities provided by OptionMetrics. Other proxies for demand pressure are considered in Section 7.

that goes long options with high margins and short options with low margin requirements. As our model predicts that the margin premium can be positive or negative depending on demand pressure, this finding suggests that margin premia are more pronounced for high-expensiveness options in our sample, leading to the negative margin premium on aggregate. To explore margin premia and their sign in more detail, we conduct portfolio double sorts, where we assign options to margin quintiles conditional on their expensiveness. We find that the long-short return of margin-sorted portfolios is indeed significantly negative for the three highest expensiveness categories (out of five). At the same time, both the magnitude and significance of the negative portfolio returns decrease with decreasing expensiveness, and margin premia even become positive for the lowest expensiveness quintile. These results suggest that option returns decrease with margin requirements for expensive options, but increase with the margin requirements for cheap options. For example, going long options with high margins and going short options with low margins yields -11.65% for the most expensive call options, but 1.61% for calls in the lowest expensiveness quintile.

Table 3 shows long-short returns and alphas of both unconditional and conditional sorts on option margins and hedging capital requirements, respectively, separated into calls (Panel A) and puts (Panel B). The first column in Panel A corresponds to the option margin long-short returns from Table 2, and the other returns are based on analogous sorts. Also for the sort by hedging capital requirements, we observe a negative long-short return for high-expensiveness options and a positive one for the low-expensiveness quintiles. These results hold for calls and for puts, with the only difference that the positive long-short return for cheap options is highly significant for puts, but not significant for calls. Overall, our sorts show that long-short returns with respect to margin requirements are monotonously decreasing in expensiveness, and the difference between the related portfolio return for high-expensiveness options and

Table 2: Portfolio sorts on option margins

This table shows delta-hedged excess returns of option margin quintile portfolios. The first line shows the result of an unconditional sort on option margins. The remaining lines show the corresponding results for double-sorted portfolios. Precisely, options are first sorted into expensiveness quintiles, then into option margin quintiles. For each of the resulting 25 portfolios, we report average excess returns, along with long-short returns in both dimensions. Significance levels are calculated using the procedure of Newey and West (1987) with 4 lags. All returns are given in monthly percent.

		Option margin					
		1 (low)	2	3	4	5 (high)	5–1
	All	-0.22	0.03	0.19	-0.47	-3.91^{**}	-3.69^{**}
Expensiveness	1 (low)	0.67	1.56^{**}	2.18^{**}	2.05	2.28	1.61
	2	-0.02	0.50	0.74	0.71	-1.96	-1.93
	3	-0.29	0.10	0.23	-0.10	-3.94^{**}	-3.65^{**}
	4	-0.32	-0.04	0.08	-0.75	-6.46^{***}	-6.14^{***}
	5 (high)	-0.72^{***}	-0.92^{***}	-1.73^{***}	-3.75^{***}	-12.37^{***}	-11.65^{***}
	5–1	-1.39^{***}	-2.48^{***}	-3.91^{***}	-5.80^{***}	-14.65^{***}	-13.26^{***}

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

the one for low-expensiveness options is highly significantly negative in all cases.

We consider different risk adjustments of the portfolio returns to rule out non-margin related effects in our return series. Specifically, we report alphas with respect to the Carhart (1997) four factor model, which includes the Fama and French (1993) factors (market excess return, size, and value) plus momentum. We also report alphas of a 5-factor model that additionally includes an option volatility factor in line with Coval and Shumway (2001). With these risk adjustments, the unconditional margin premium for call options is no longer significant. On the other hand, the positive long-short returns for low-expensiveness calls become significant now as well, while there are no notable changes for the other conditional results.

The empirical findings confirm the predictions of our model. More precisely, Corollary 2a) predicts that option returns decrease with both the option margin and the hedging capital

Table 3: Excess returns and alphas of expensiveness-margin portfolios

This table shows long-short returns and alphas of quintile portfolios on option margins and hedging capital, respectively. In the first line, we report results from unconditional sorts, the remaining lines correspond to double-sorted portfolios. Precisely, at the beginning of each month, options are first sorted into expensiveness quintiles, then into quintiles on option margins and hedging capital, respectively. We form margin long-short returns within each expensiveness quintile and report the corresponding time-series averages and alphas. Finally, the last line shows the return slope, i.e., the difference between long-short returns in the highest and lowest expensiveness quintile. Four factor alphas are computed with respect to market excess return, size, book-to-market (Fama and French, 1993) and momentum (Carhart, 1997). The five factor alpha includes an additional zero-beta index straddle return factor (Coval and Shumway, 2001). Significance levels are calculated using the procedure of Newey and West (1987) with 4 lags. All returns and alphas are given in monthly percent.

Panel A: Call options

		Option margin long-short			Hedging capital long-short		
		Return	$\alpha(4)$	$\alpha(5)$	Return	$\alpha(4)$	$\alpha(5)$
	All	−3.69**	−1.47	−1.30	−2.01*	−0.48	−0.32
Expensiveness	1 (low)	1.61	3.96**	4.15**	1.59	3.11**	3.29**
	2	−1.93	0.15	0.41	0.06	1.56	1.81
	3	−3.65**	−1.33	−1.25	−1.41	0.27	0.42
	4	−6.14***	−3.75***	−3.64***	−3.74***	−2.02**	−1.89**
	5 (high)	−11.65***	−9.68***	−9.61***	−7.20***	−5.86***	−5.74***
	5–1	−13.26***	−13.63***	−13.77***	−8.79***	−8.97***	−9.02***

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Panel B: Put options

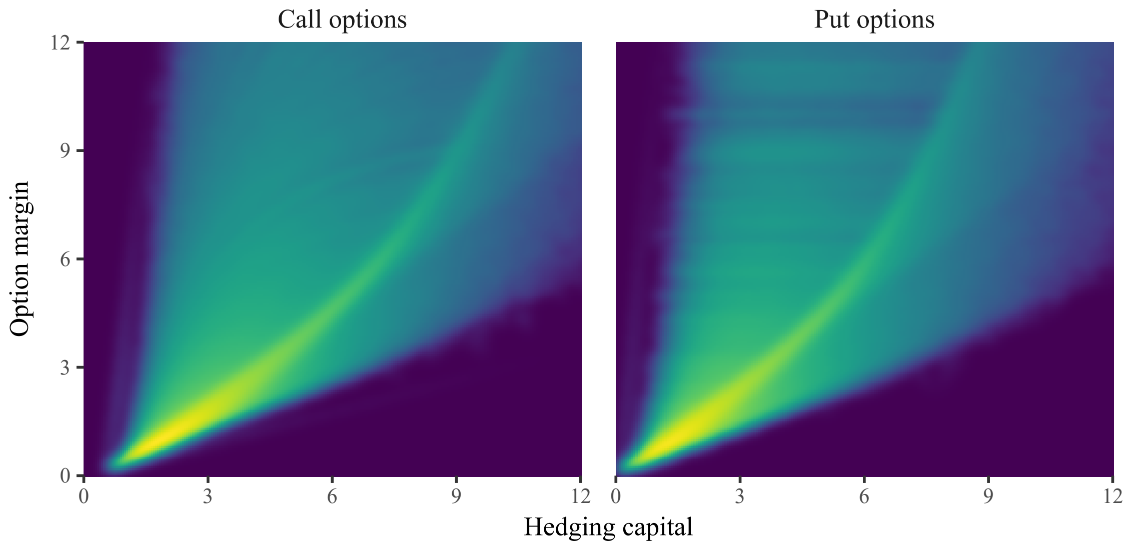
		Option margin long-short			Hedging capital long-short		
		Return	$\alpha(4)$	$\alpha(5)$	Return	$\alpha(4)$	$\alpha(5)$
	All	0.08	1.10	1.30	−0.02	0.82	0.99
Expensiveness	1 (low)	1.90**	2.72***	2.86***	1.78**	2.39***	2.49***
	2	1.46	2.19**	2.37***	1.23	1.82**	1.98**
	3	0.91	1.80*	1.97**	0.58	1.25	1.40*
	4	0.02	1.22	1.47	−0.50	0.46	0.67
	5 (high)	−3.23***	−1.94	−1.71	−3.06***	−1.91	−1.71
	5–1	−5.13***	−4.65***	−4.57***	−4.84***	−4.30***	−4.20***

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

when end-users are long, which is clearly confirmed by the highly significantly negative long-short return for high-expensiveness options. For options in which end-users are short, Corollary 2b) predicts that option returns increase with the margin on the stock position as the option dealers are now on the other side of the market. Our empirical results confirm this prediction for put options, and the respective returns for call options are positive, but not significant. On the other hand, there should be no cross-sectional effect of the (short) option margin in this case, as the option dealers are long and the relative (long) margin they have to post is identical for all options. Yet, we do find a significant cross-sectional return difference for puts. Taking a closer look at the margin data suggests that these contradictory results may be driven by the empirical regularity that hedging capital requirements are high (low) when option margins are high (low), as illustrated in Fig. 8. Due to this correlation between hedging capital and option margins, the double sorts may not be able to disentangle the associated effects on option returns, but we will be able to do so in our regression analysis that follows next.

Figure 8: Relation between option margins and hedging capital

This figure visualizes the relation between option margins and hedging capital. First, we round all option margins and hedging capital to one decimal place. Then we group all options into bins based on these rounded values. For each bin, the color at the corresponding coordinate indicates the frequency of this combination.



5 Regression Analysis

The portfolio sorts in the previous section strongly suggest that a significant margin premium is priced in the cross-section of option returns, in line with the predictions of our model. To corroborate this evidence, we run Fama-MacBeth regressions, which enhances our analysis along three dimensions: First, we estimate actual slope coefficients for margin-related effects instead of relying on return differences of high- and low-margin portfolios. Second, the regression approach allows us to include several control variables as potential drivers of option returns. Third, by including both types of margin requirements – the option margin and the hedging capital – in a regression model, we are able to disentangle the associated effects on option returns.

Since our results in Section 4 suggest that margin requirements induce a similar premium for call and put option returns, we run the regressions on the combined sample of both option types.[21]

To test for the demand pressure-conditional margin premium effects predicted by our model, we allow the slope coefficients on margin requirements to be different across expensiveness levels. More specifically, we assign options to expensiveness quintiles and run monthly cross-sectional regressions of delta-hedged option returns on option margins m and hedging capital $\widetilde{m}$,

$$r_{i,t+1} = \alpha + \sum_{k=1}^{5} \left(\mathbf{1}_{\{i \in q_k\}} \beta_k \, m_{i,t} + \mathbf{1}_{\{i \in q_k\}} \gamma_k \, \widetilde{m}_{i,t} \right) + \text{control variables} + \varepsilon_{i,t+1}, \tag{15}$$

where $\mathbf{1}_{\{i \in q_k\}} = 1$ if option i belongs to expensiveness quintile q_k, and zero otherwise.

Table 4 reports the regression results. Specifications (i) and (ii) present results for regressing delta-hedged option returns either on the required option margins or on the required hedging capital. These regressions unanimously confirm the results of the portfolio sorts: In both cases, there is a significantly negative coefficient for margin requirements in the high-expensiveness quintiles, and a significantly positive one for low-expensiveness options.

We enrich these models by including several option-, stock-, and firm-specific control variables in models (iii) and (iv). In particular, we control for the options' open interest, delta, time to maturity, gamma and vega. Controls for stock characteristics are chosen along the lines of Christoffersen et al. (2015): We include the underlying stock's GARCH volatility estimate and its systematic risk proportion (defined as the square root of the R-square from the regression

[21] Separate analyses for call and put options yield similar results, as shown in the Internet Appendix.

Table 4: Fama-MacBeth regressions

This table reports Fama-MacBeth regression results of monthly delta-hedged option returns. The considered option sample consists of all call options and put options with an ex-ante delta of at most −0.2. Dependent variables are the options' margin and hedging capital requirements. We estimate segmented regression coefficients based on expensiveness quintiles, which are formed at the beginning of each month. Below, *option margin (k)* and *hedging capital (k)* refer to the respective margin variable for options within the k-th expensiveness quintile. Control variables on the option level are the relative bid-ask spread, the logarithm of the option's open interest, delta, gamma, vega, as well as time to maturity in days. In addition, we include a GARCH estimate of the underlying stock's historical volatility, its systematic risk proportion, as well as the firms' size and balance sheet leverage. All coefficients are given in percent, significances are based on Newey-West standard errors with 4 lags.

Model	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Option margin (1)	0.69***		0.70***		0.14	0.15
Option margin (2)	0.10		0.09		−0.15*	−0.10
Option margin (3)	−0.20*		−0.22**		−0.28**	−0.20*
Option margin (4)	−0.61***		−0.64***		−0.52***	−0.43***
Option margin (5)	−1.14***		−1.15***		−0.56***	−0.48***
Hedging capital (1)		0.97***		0.81**	0.97***	0.84***
Hedging capital (2)		−0.03		−0.34	0.34	0.04
Hedging capital (3)		−0.58**		−0.97***	−0.14	−0.52*
Hedging capital (4)		−1.24***		−1.69***	−0.47**	−0.92***
Hedging capital (5)		−2.50***		−2.99***	−1.67***	−2.14***
Log(open interest)			−0.31***	−0.30***		−0.28***
Delta			−0.33***	0.20		−0.07
Time to maturity			0.01**	0.00		0.00
Gamma			3.42	10.90**		4.71
Vega			0.02***	0.05***		0.02**
Stock volatility			−0.39***	−1.00***		−0.87***
Systematic risk			1.52	1.25		1.01
Firm size			0.30***	0.36***		0.34***
Firm leverage			0.36	0.71		0.60
Constant	0.38	1.77***	−5.55**	−2.00	1.17***	−2.50
Average R^2	0.04	0.04	0.05	0.06	0.05	0.07

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

of stock returns on Fama-French and momentum factors, as in Duan and Wei, 2009). Finally, firm size (measured as the logarithm of market capitalization) and firm leverage (the value of equity divided by the sum of long-term debt and the par value of preferred stock) are included. We find that our results are robust to controlling for all these effects. While especially the options' bid-ask spread, the open interest, and the underlying stock volatility seem to be significant drivers of option returns, the effect of margin requirements is almost unaffected when we include these variables.

Finally, we run regressions that include both the option margin and the hedging capital requirement as explanatory variables. The results for specifications (v) and (vi) concisely match the cross-sectional predictions of our model. Consistent with Corollary 2a), we find that margin premia are significantly negative for expensive options, both for the options margin as well as the hedging capital requirement. In line with Corollary 2b), we find that, on the one hand, the premium for the hedging capital requirement is significantly positive for the least expensive options. On the other hand, there is no significant return differential for cheap options with high compared to low option margin requirements. These results are robust to the inclusion of control variables in specification (vi).

6 Margin Premia and Funding Liquidity

In the previous sections, we have presented evidence that margin requirements are priced in the *cross-section* of equity options, consistent with the predictions of our model. In our model, premia arise from compensation that dealers require for taking unhedgeable risk as well as for funding costs. Hence, margin premia should also vary in the *time series* if funding conditions change over time.

To test this hypothesis, we separately analyze periods of low and high funding illiquidity, respectively, which we identify using the 3-month TED spread and Broker-Dealer leverage as proxies for funding constraints. The latter is defined as the ratio of total financial assets over equity based on the Federal Reserve *Flow of Funds* data, in line with Adrian, Etula and Muir (2014). We assign a given month to the high (low) funding cost subsample if the respective measure is above (below) its full-sample median value. Table 5, Panel A shows average call option portfolio returns from a double sort on option expensiveness and our margin variables after controlling for the 3-month TED spread.[22] In Panel B, we repeat the same analysis for the level of broker-dealer leverage. Throughout all specifications, we find much larger margin premia when funding costs are high. For example, the overall effect of option margins in call options is 18.62% per month when the TED spread is large, otherwise it is only 7.90%.

To provide further evidence that margin premia are related to funding conditions, we use the insights of our model to define an option returns-implied measure of funding costs.[23] We then show that the time series of estimated funding costs is correlated the measures of funding liquidity.

Our model implies, and our empirical results confirm, that option returns reflect significantly negative premia for hedging capital and option margin requirements for expensive options and a significantly positive premium for hedging capital requirements for cheap options. Drawing on the double sort-setup that we use in the model simulation and in the empirical analysis, we use $r_{t+1}^{i,j}$ to denote the average return of options in the j-th margin quintile portfolio within the i-th expensiveness quintile portfolio. Options in quintiles $i = 1$ ($i = 5$) are cheap

[22] Results for put options are similar and may be found in the Internet Appendix, Table IA.4.

[23] Our approach is related to other recent work that uses market-based funding liquidity measures, such as Chen and Lu (2016) and Golez, Jackwerth and Slavutskaya (2016). They motivate the use of market-based funding liquidity measures by arguing that such measures might be more suitable to describe the actual funding situation of investors than measures based on stated interest rates.

Table 5: Portfolio sorts conditional on the level of funding costs (Call options)

This table shows long-short returns of call option quintile portfolios formed on option margins and hedging capital, respectively, for different levels of funding costs. We split our sample in periods of low and high funding costs based on a median-split of the TED spread. In each subsample, we run monthly double sorts on option expensiveness and the respective margin variable, and calculate long-short returns in the margin dimension. We report time-series averages with Newey and West (1987) significance levels using 4 lags. All returns are given in monthly percent.

Panel A: TED spread median-split

		Option margin long-short		Hedging capital long-short	
	Funding costs	low	high	low	high
Expensiveness	1 (low)	−3.15	6.36*	−1.87	5.06**
	2	−5.15**	1.29	−2.46	2.58
	3	−8.14***	0.85	−4.33***	1.50
	4	−8.48***	−3.79*	−5.25***	−2.23
	5 (high)	−11.05***	−12.25***	−7.27***	−7.13***
	5–1	−7.90***	−18.62***	−5.40***	−12.19***

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Panel B: Broker-Dealer leverage median-split

		Option margin long-short		Hedging capital long-short	
	Funding costs	low	high	low	high
Expensiveness	1 (low)	−4.66	7.64***	−2.49	5.52**
	2	−5.71**	1.71	−2.56	2.58
	3	−7.49***	0.06	−4.11***	1.19
	4	−9.11***	−3.27*	−5.67***	−1.89
	5 (high)	−12.23***	−11.04***	−7.97***	−6.46***
	5–1	−7.57**	−18.68***	−5.48***	−11.98***

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

(expensive) and options in quintiles $j = 1$ ($j = 5$) are associated with low (high) margin requirements, respectively. Denoting the portfolio's average hedging capital by $\widetilde{m}_t^{i,j}$ and the average option margin by $m_t^{i,j}$, we obtain from Proposition 3 that the expected long-short returns of buying high and selling low margin options, $\mathrm{E}_t\left(ls_{t+1}^i\right)$, are[24]

$$\begin{aligned}
\mathrm{E}_t\left(ls_{t+1}^1\right) &= \mathrm{E}_t\left(r_{t+1}^{1,5} - r_{t+1}^{1,1}\right) = \psi_t\left(\widetilde{m}_t^{1,5} - \widetilde{m}_t^{1,1}\right) && =: \psi_t \times \overline{m}_t^1, \\
\mathrm{E}_t\left(ls_{t+1}^5\right) &= \mathrm{E}_t\left(r_{t+1}^{5,1} - r_{t+1}^{5,5}\right) = \psi_t\left(m_t^{5,5} - m_t^{5,1} + \widetilde{m}_t^{5,5} - \widetilde{m}_t^{5,1}\right) && =: \psi_t \times \overline{m}_t^5.
\end{aligned} \tag{16}$$

These equations show that normalizing the long-short returns by the corresponding differentials in margin requirements provides us with the implied funding spread ψ_t, and we define

$$\widehat{\psi}_{t,t+1} = \frac{ls_{t+1}^1 + ls_{t+1}^5}{\overline{m}_t^1 + \overline{m}_t^5}. \tag{17}$$

as our measure of funding liquidity.[25]

We compute the time-series of $\widehat{\psi}_{t,t+1}$ using the double-sorted option portfolio returns from Section 4, as the equally-weighted average of estimates implied by call and put options, respectively. To test the relation of our measure to funding liquidity, we run time-series regressions on the TED spread, Broker-Dealer leverage, and control variables.

The results in Table 6 show that our funding proxy is positively related to both the Broker-Dealer leverage and the TED spread at the time of portfolio formation. Additionally, we find

[24] To fix ideas, we assume that options in the lowest (highest) expensiveness quintile are throughout subject to negative (positive) end-user demand pressure. In addition, we assume that there either is no unhedgeable risk or that the premia on unhedgeable risk are homogeneous across expensiveness-margin portfolios, so that they cancel out.

[25] From a conceptual point of view, we could estimate ψ from the long-short returns of either the expensive or the cheap options. In our empirical application, we combine both with the intention to make the measure robust to time-variation in demand pressure and or other variables that might have different effects on cheap versus expensive options.

Table 6: Regression analysis of the funding liquidity measure

This table shows results from time series regressions of the funding liquidity measure on the lagged 3-month TED spread and its contemporary change. We include the average return of all considered options and the lagged return of the proxy variable as controls. All variables are given in monthly percent. The standard errors are calculated using the Newey-West estimator with a lag length of 4 months.

Model	(i)	(ii)	(iii)	(iv)	(v)
Lagged TED spread	6.07^{***}	5.29^{***}	5.74^{***}		
	(2.07)	(1.93)	(2.16)		
Change in TED spread		-3.93^{*}			
		(2.23)			
Broker-Dealer leverage				0.03^{*}	0.02^{*}
				(0.02)	(0.01)
Average option return			0.00		0.00
			(0.01)		(0.01)
Lagged proxy return			0.14		0.16
			(0.10)		(0.10)
Constant	0.34^{***}	0.37^{***}	0.27^{***}	-0.07	-0.10
	(0.10)	(0.11)	(0.10)	(0.38)	(0.32)
Adjusted R^2	0.04	0.05	0.06	0.01	0.03

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

that options-implied funding liquidity is negatively related to changes in the TED spread. This result is consistent with the notion that a tightening of funding conditions is associated, on the one hand, with an increase in *expected* margin premia, and, on the other hand, with *contemporaneously realized* margin premia being low. These findings are robust to the inclusion of average option returns and lagged proxy returns.

In summary, these results provide supportive evidence for the funding channel of margin premia in option returns featured by our model. Specifically, the significant link between option-implied funding liquidity and both the TED spread and Broker-Dealer leverage confirms Corollary 2c) that the price impact of margins strengthens with funding constraints.

7 Robustness Checks

We perform several robustness checks to ensure that our results do not depend on the specific design of our empirical analysis. In particular, we show that our findings are robust to modifications of the sample selection procedure as well as to alternative specifications of the margin requirements and other important variables.

Margin variables In the model and the empirical analysis above, we assume independent option and stock margins, thereby neglecting potential margin reductions due to hedging activities. We now show that the margin effects documented above are robust to using more sophisticated portfolio margin rules.

Specifically, the CBOE introduced new portfolio margin rules in April 2007, which may be used as an alternative to the strategy-based margin requirements. Under portfolio margining, margin requirements are calculated to reflect the overall risk of an investor's portfolio. To calculate the margin requirements, an investor's option positions are grouped by their respective underlying, together with potential positions in the underlying itself. Each of the resulting sub-portfolios is then evaluated at ten hypothetical market scenarios. For example, in the case of equity options, the price of the underlying asset is assumed to move along ten equidistant points in the range between -15% and $+15\%$ from the current market value. For each scenario, option values are calculated with a theoretical model, resulting in a hypothetical value for the sub-portfolio. The margin requirement for this sub-portfolio is then defined as the lowest portfolio value among these evaluation points, but no less than \$.375 per option contract. The investor's total margin requirement is defined as the sum of the margin requirements of all sub-portfolios.

Since we cannot observe (all real-world) investor portfolios, we follow Leippold and Su (2015) and construct two hypothetical benchmark portfolios, containing either a naked short option position or a delta-hedged short option position, respectively. We compute the portfolio margin requirements following the CBOE's scenario approach, using the Black-Scholes model, and present margin premia from expensiveness/margin double sorts in Table 7. For both portfolios, we find that long-short margin returns decrease from low expensiveness to high expensiveness options and that the difference is highly significant.

Table 7: Conditional sorts on portfolio margins

This table shows long-short returns on portfolio margins, conditional on expensiveness. Specifically, we sort options into expensiveness quintiles, then into quintiles of the portfolio margin of a naked short option and a delta-hedged short position, respectively. We report average long-short returns per expensiveness group and the resulting return slope across expensiveness. All returns are given in monthly percent, significances are based on Newey and West (1987) standard errors with 4 lags.

		Naked		Delta-hedged	
		Call options	Put options	Call options	Put options
Expensiveness	1 (low)	1.64	1.98**	1.63	1.97**
	2	−0.28	1.37	−1.40	1.30
	3	−2.10	0.63	−3.02*	0.70
	4	−4.82***	−0.31	−6.29***	−0.31
	5 (high)	−9.73***	−3.31***	−13.34***	−3.27***
	5–1	−11.37***	−5.29***	−14.97***	−5.24***

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Demand proxy In our baseline specification, we use options' expensiveness to measure price pressure. This approach is motivated by our model as well as empirical evidence that expensiveness is directly related to demand pressure (Gârleanu, Pedersen and Poteshman, 2009). Ideally, we would like to verify this link in our options sample using data on end-user demand, however, such data is generally not available. To construct a proxy for demand, we use data on customer trades from the International Securities Exchange (ISE).[26] A caveat for the subsequent analysis is the limited coverage that the ISE data provides for our sample. While we have no reason to believe that this limited coverage results in systematic biases, one should bear in mind that (i) the ISE data only starts in 2005, whereas our OptionMetrics sample starts in 1996; (ii) over the joint period from 2005 to August 2013 the ISE data only covers approximately 60% of the options in our sample; (iii) the ISE has an average market share of only 20% over our sample period. For more details on the ISE sample coverage, see Table IA.5 in the Internet Appendix.

We use daily ISE data on customer buy and sell volumes to construct the time-t demand proxy for option j as the cumulative differences in buy and sell volumes, from the option's inception date up to t. In other words, the idea is to measure changes in the aggregate holdings of option j. To allow for a comparison across different options, we scale the volume differentials by the option's open interest,

$$\text{ISE demand}_{t,j} = \frac{\sum_{\tau \leq t} \left(\text{BuyVol}_{\tau,j}^{\text{customer}} - \text{SellVol}_{\tau,j}^{\text{customer}} \right)}{\text{OpenInterest}_{t,j}}. \tag{18}$$

The results in Table 8 show that our expensiveness sorts indeed reflect significant differences in demand for cheap compared to expensive options. For both, calls and puts, we find that expensive options are associated with much higher demand than cheap options. Hence, these results provide supporting evidence for the notion that expensiveness reflects demand pressure.[27]

[26] Gârleanu, Pedersen and Poteshman (2009) argue that firm (proprietary) traders are more similar to market makers. Accordingly, we only use customer trading volume, but our results are robust to the inclusion of firm trades.

[27] We have conducted several other empirical exercises with the ISE data, for instance, using ISE demand proxies in double sorts with margin requirements. While we find that the margin premium results for call options are qualitatively the same as the findings reported in the paper, the results are somewhat waker for

Table 8: Relation between expensiveness and ISE demand

This table shows the average ISE demand of value-weighed quintile portfolios formed on expensiveness. Significance levels are calculated using the procedure of Newey and West (1987) with 4 lags. ISE demand is given in percent.

Expensiveness	Call options	Put options
1 (low)	-1.23^{***}	-3.64^{***}
2	-0.64^{**}	-2.34^{***}
3	0.10	-1.97^{***}
4	0.88^{***}	-1.44^{***}
5 (high)	2.95^{***}	-0.63
5–1	4.18^{***}	3.01^{***}

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Variance risk In our empirical analysis we study the cross-section of delta-hedged option returns. While the return patterns match the predictions of our model, a natural concern might be that these returns reflect higher moment risks that the delta-hedge cannot eliminate. Bakshi and Kapadia (2003), for example, show that delta-hedged gains of options written on a market index provide compensation for variance risk. More recently, empirical evidence that variance risk is priced has been documented in several asset classes, and we therefore explore whether or how our results are related to variance risk premia.

We compute (firm-level) variance risk premia as the difference in objective and risk-neutral variance. More specifically, we follow the model-free approach of Carr and Wu (2009), who synthesize variance swap rates from portfolios of out-of-the-money (OTM) options building on the earlier work of Bakshi, Kapadia and Madan (2003). The time-t variance risk premium

put options. Importantly, we find that expensiveness/margin double sorts in the subsample for which ISE data is available lead to very similar results as the demand/margin double sorts. One the one hand, this suggests that the significance of the margin premium results is affected by the limited coverage of ISE data in the time-series and in the cross-section, but on the other hand this confirms the link between demand and expensiveness.

is given by

$$VRP(t,T) = V^{\mathbb{P}}(t,T) - V^{\mathbb{Q}}(t,T). \tag{19}$$

The risk-neutral variance, $V^{\mathbb{Q}}(t,T)$, can be computed from a portfolio of OTM options,

$$V^{\mathbb{Q}}(t,T) = \int_{S(t)}^{\infty} \frac{2(1-\ln(\frac{K}{S(t)}))}{K^2} C(t,T;K)\,dK + \int_{0}^{S(t)} \frac{2(1+\ln(\frac{S(t)}{K}))}{K^2} P(t,T;K)\,dK, \tag{20}$$

where $C(t,T;K)$ and $P(t,T;K)$ is the price of a call and put option, respectively, with strike price K and maturity in T. As a proxy for the objective variance $V^{\mathbb{P}}(t,T)$, we compute the realized variance over the preceding six months.

To show that variance risk cannot explain the margin premium, we first extend our portfolio double sorts to triple sorts. That is, each month, we first sort firms into quintile portfolios based on their variance risk premium and subsequently we conduct the expensiveness/option margin double sort within each of the VRP-quintiles. Table 9 presents the results for the lowest VRP-quintile (with an average VRP of −16.73%) and the highest VRP-quintile (with an average VRP of 20.08%) in Panels A and B, respectively.[28] The cross-sectional return patterns are very similar in both VRP-quintiles. Specifically, we find very similar to the results in Table 2 and consistent with our model, that margin premia are positive for cheap options whereas they are negative for expensive options, and that the difference in these margin premia is highly significant. These results suggest that variance risk cannot explain the effects of margin requirements on option returns that we document in this paper.

Additionally, we repeat our Fama-MacBeth regression analyses with controls for variance risk. The first two columns of Table 10 show the baseline specification without and with the standard control variables.[29] Regression models (iii) and (iv) show that these results do not

[28] Results for put options and hedging capital are very similar and skipped for brevity.

[29] The small deviations from Table 4 is a result from the slightly smaller sample of options with an estimate

Table 9: Triple sort on variance risk premium, expensiveness, and option margins

This table shows value-weighted excess returns of call option portfolios. Each month, we form quintile portfolios on the stock-specific variance risk premium, option expensiveness and option margins. Panel A and B show the expensiveness-margin portfolios in the lowest and highest variance risk quintile portfolio, respectively. All returns are given in monthly percent, significances are based on Newey and West (1987) standard errors with 4 lags.

Panel A: Low VRP (−16.73% on average)

		Option margin					
		1 (low)	2	3	4	5 (high)	5–1
Expensiveness	1 (low)	0.64	2.05***	2.91**	3.22*	3.14	2.50
	2	−0.22	−0.03	0.17	0.09	−4.09*	−3.87*
	3	−0.54	−0.04	−0.14	−1.27	−7.60***	−7.07***
	4	−0.80**	−1.13**	−1.41**	−4.26***	−11.01***	−10.21***
	5 (high)	−2.65***	−2.71***	−4.45***	−7.20***	−16.23***	−13.58***
	5–1	−3.29***	−4.76***	−7.36***	−10.42***	−19.37***	−16.08***

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Panel B: High VRP (20.08% on average)

		Option margin					
		1 (low)	2	3	4	5 (high)	5–1
Expensiveness	1 (low)	0.85	1.85**	3.06***	3.02*	4.78*	3.93
	2	0.28	0.90	1.12	1.20	−0.93	−1.21
	3	−0.21	0.41	0.28	0.56	−4.89**	−4.68**
	4	−0.31	−0.30	0.10	−0.31	−6.54***	−6.23***
	5 (high)	−0.28	−0.49	−0.86*	−2.46***	−11.53***	−11.25***
	5–1	−1.13***	−2.34***	−3.92***	−5.48***	−16.31***	−15.18***

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

change once we include the variance risk premium as an additional control variable. Since the relation between option returns and variance risk premia is likely to be non-linear, we follow the ideas of Bakshi, Kapadia and Madan (2003) to approximate the variance risk component in expected option *returns* using the option's time-t vega (ν) and the stock-specific variance risk premium. More specifically, we define a scaled variance risk premium as

$$\text{VRP (scaled)} = \frac{\text{VRP} \cdot \nu}{F}. \tag{21}$$

The last two columns of Table 10 show that VRP (scaled) cannot explain the margin premium. In summary, our analyses provide compelling evidence that variance risk cannot explain our results. While there is a link between expensiveness and variance risk premia by definition, the cross-sectional patterns in delta-hedged option returns, which support the notion of margin premia, are robust to controlling for variance risk premia.

Moneyness-Maturity subsamples Our main analyses are based on a rather large option sample. To verify that our results are not driven by moneyness patterns or outliers, we form double-sorted portfolios for a range of subsamples. Specifically, we group options into five bins by months to maturity and the absolute value of delta, respectively. For each subsample, we run a similar portfolio analysis as discussed in Section 4. That is, we first sort options into expensiveness quintiles. Then, we form margin quintiles conditional on expensiveness and calculate the corresponding margin long-short return as difference between the returns of the highest and lowest margin quintile portfolio. To quantify the overall margin effect, we calculate the difference between the margin long-short return in the highest and lowest expensiveness quintile. Table 11 shows the time-series averages of these return slopes. Almost

for the variance risk premium.

Table 10: Fama-MacBeth regressions with variance risk premia

This table reports Fama-MacBeth regression results of monthly delta-hedged option returns. The considered option sample consists of all call options and put options with an ex-ante delta of at most −0.2. Dependent variables are the options' margin and hedging capital requirements. We estimate segmented regression coefficients based on expensiveness quintiles, which are formed at the beginning of each month. Below, *option margin (k)* and *hedging capital (k)* refer to the respective margin variable for options within the k-th expensiveness quintile. *VRP* refers to the stock-level variance premium, *VRP (scaled)* to the vega-weighted variance risk premium relative to the options' price. In regression models (ii), (iv), and (vi), we include the same control variables as in Table 4. All coefficients are given in percent, significances are based on Newey-West standard errors with 4 lags.

Model	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Option margin (1)	0.17	0.17	0.16	0.16	0.17	0.18
Option margin (2)	−0.16**	−0.12*	−0.17**	−0.13**	−0.17**	−0.13*
Option margin (3)	−0.24**	−0.18	−0.25**	−0.18	−0.25**	−0.18
Option margin (4)	−0.51***	−0.43***	−0.51***	−0.43***	−0.52***	−0.44***
Option margin (5)	−0.53***	−0.44***	−0.52***	−0.44***	−0.54***	−0.46***
Hedging capital (1)	0.89***	0.78***	0.95***	0.85***	0.96***	0.83***
Hedging capital (2)	0.29	0.02	0.32	0.05	0.30	0.01
Hedging capital (3)	−0.21	−0.58*	−0.20	−0.56*	−0.21	−0.61**
Hedging capital (4)	−0.53***	−0.96***	−0.53***	−0.96***	−0.54***	−1.00***
Hedging capital (5)	−1.71***	−2.17***	−1.76***	−2.21***	−1.78***	−2.25***
VRP			−3.27***	−3.30***		
VRP (scaled)					−2.19***	−2.15***
Constant	1.36***	−1.99	1.30***	−3.16	1.24***	−3.94
Controls	No	Yes	No	Yes	No	Yes
Average R^2	0.05	0.07	0.06	0.07	0.06	0.07

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

all return slopes are significantly negative, underpinning the previous results.

Table 11: Delta-maturity subsample analysis

In this table, we analyze the magnitude of conditional margin long-short returns for several subsamples on delta and time to maturity. Within each subsample, we first sort all options into expensiveness quintiles. Then, we form margin quintiles conditional on expensiveness. To quantify the margin effect, we report the average difference of margin-long short returns in the highest and lowest expensiveness quintile. Below, we report time-series averages of these return slopes for each subsample. Significance levels are calculated using the procedure of Newey and West (1987) with 4 lags. All returns and alphas are given in monthly percent.

Panel A: Subsamples on delta

	Option margin		Hedging capital	
Abs. delta	Call options	Put options	Call options	Put options
0.0–0.2	−24.97***	−6.80**	−21.03***	−15.79***
0.2–0.4	−9.67***	−4.69***	−8.83***	−4.91***
0.4–0.6	−3.26***	−3.64***	−3.53***	−3.63***
0.6–0.8	−2.10***	−3.44***	−1.92***	−3.28***
0.8–1.0	−1.71***	−2.11***	−1.65***	−2.36***

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Panel B: Subsamples on time to maturity

	Option margin		Hedging capital	
Months	Call options	Put options	Call options	Put options
1	−27.98***	−7.70***	−17.36***	−6.09***
2	−17.28***	−4.92***	−9.12***	−3.50***
3	−16.87***	−1.95**	−11.27***	−1.82
4-6	−7.76***	−2.21***	−5.40***	−2.07***
7-12	−3.38**	−1.32**	−2.56**	−1.70**
>12	−3.67**	−1.40***	−3.11***	−1.24***

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Further robustness checks We exclude deep-out-of-the-money puts in our main analyses since these options realize enormous returns in market declines, which distort the portfolio sorts and regressions. As shown in the first column of Table IA.6.B, without restrictions on moneyness, margin long-short returns of put options are still monotonously decreasing in expensiveness, but the return slope of −2.88 is not statistically significant. If we remove all option-months containing at least one daily option return of more than 1 000%, the overall margin effect for put options increases to highly significant 6.91% per month, as shown in the second column. So even this rather innocuous filter criterion on extreme returns has a significant impact on put results, whereas call returns show almost no change.

As shown in the third column, we also find a more pronounced margin effect if we change our specification from value weighting to equal weights. With equal weighting, we have larger positions in illiquid options, where the role of option dealers is more important, resulting in larger long-short return due to their funding costs.

The margin effect is also robust to other choices of the expensiveness proxy. For example, we repeat our analysis with a historical baseline volatility estimated over the preceding 60 instead of 365 days. Although this measure adjusts faster to changing stock volatility, it is subject to higher estimation error. Nevertheless, we also find a significant margin effect under this specification.

To rule out potential distortions by small firms with illiquid options, we repeat our analysis also for the subsample consisting of options on S&P 500 index (SPX) members. As shown in the fifth column, we find for call (put) options a highly significant overall margin effect of 11.12% (5.29%), which is in the same order of magnitude as the margin premium in the full sample.

We have argued that the conditional margin premia are different from the unconditional leverage effect documented by Frazzini and Pedersen (2012). As an additional check on this hypothesis, in the last column, we present regression alphas of long-short returns with respect to the betting against beta (BAB) leverage factor, which goes long low leverage options and short high leverage options. These alphas are decreasing in expensiveness and highly significant for both call and put options, as expected.

8 Conclusion

This paper shows that a *margin premium* is priced in the cross-section of equity option returns. The margin premium compensates funding-constrained option dealers for the capital that is tied up when they satisfy the option demand of end-users. In addition to the margin requirement for the option itself, capital is also required for hedging the options position in the underlying market. To identify the margin premium empirically, it is crucial to realize that its sign depends on whether option dealers take the long or the short side of the market. Taking demand pressure into account, the returns of options portfolios sorted by margin requirements decrease with margins when option dealers are short, but increase with margin requirements when option dealers are on the long side of the market. We confirm these findings in Fama-MacBeth regressions, controlling for several other drivers of option returns suggested by previous research.

Finally, we use the time series of margin long-short portfolio returns to construct an option-market based measure for funding liquidity. Our funding measure is significantly correlated with the TED spread and Broker-Dealer leverage, which confirms that margin requirements affect option returns through the funding channel.

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A Proofs

Proof of Proposition 1. The maximization problem given in Eq. (1) together with Eq. (3) is equivalent to maximizing the function

$$\begin{aligned} f(\theta, q) =&(\eta+\theta)\bar{\mu}_S + q\bar{\mu}_F - \frac{\gamma}{2}\left((\eta+\theta)^2\sigma_S^2 + 2(\eta+\theta)q\sigma_{SF} + q^2\sigma_F^2\right) \\ &- \psi\left(|\theta|\,\widetilde{M} + |q|\left(\mathbf{1}_{\{q>0\}}M^+ + \mathbf{1}_{\{q<0\}}M^-\right)\right). \end{aligned} \tag{22}$$

For $q, \theta \neq 0$, this function is differentiable, and setting both partial derivatives to zero yields

$$\begin{aligned} \theta &= \frac{1}{\gamma\sigma_S^2}\left(-q\gamma\sigma_{SF} - \psi\,\mathrm{sgn}(\theta)\widetilde{M}\right), \\ q &= \frac{1}{\gamma\sigma_F^2}\left(\bar{\mu}_F - (\eta+\theta)\gamma\sigma_{SF} - \psi\,\mathrm{sgn}(q)M^{sgn(q)}\right). \end{aligned} \tag{23}$$

In equilibrium, we have $q = -d$, which implies θ as given by Eq. (4). The solution is defined (and optimal) as long as $|\gamma\sigma_{SF}d| > \psi\widetilde{M}$. □

Proof of Proposition 2. Inserting Eq. (4) in Eq. (23), we get

$$\begin{aligned} q &= \frac{1}{\gamma\sigma_F^2}\left(\bar{\mu}_F - \left(\eta + (d\Delta - \frac{\psi}{\gamma\sigma_S^2}\,\mathrm{sgn}(d\Delta)\widetilde{M})\right)\gamma\sigma_{SF} - \psi\,\mathrm{sgn}(q)M^{sgn(q)}\right) \\ \Leftrightarrow \bar{\mu}_F &= \Delta\bar{\mu}_S - d\gamma(\sigma_F^2 - \Delta\sigma_{SF}) - \mathrm{sgn}(d)\psi(M + |\Delta|\,\widetilde{M}). \end{aligned} \tag{24}$$

Rearranging $\bar{\mu}_F = \mathrm{E}_t(F_{t+1} - R^f F_t)$ to the option price gives the result.

If the end-user demand is zero, the dealer's optimal excess stock position is $\theta = 0$ by construction. By the optimality of the dealer's option position, we get

$$q = \frac{1}{\gamma\sigma_S^2}\left(\bar{\mu}_F - \eta\gamma\sigma_{SF}\right) \overset{!}{=} 0, \tag{25}$$

which in turn is equivalent to

$$\bar{\mu}_F = \eta\gamma\sigma_{SF} = \Delta\bar{\mu}_S. \tag{26}$$

Rearranging this formula yields

$$F_t = \mathrm{E}\left(\frac{F_{t+1} - \Delta\bar{\mu}_S}{R^f}\right) \equiv F_t^0. \tag{27}$$

Finally, note that $\sigma_F^2 - \Delta\sigma_{SF} = \sigma_F^2(1 - \frac{\sigma_{SF}^2}{\sigma_F^2\sigma_S^2}) = \sigma_F^2(1 - (\mathrm{corr}_t(F_{t+1}, S_{t+1}))^2) \geq 0$. Therefore, we get that

$$F_t - F_t^0 = d\, \underbrace{\gamma \frac{\sigma_F^2 - \Delta\sigma_{SF}}{R^f}}_{\geq 0} + \mathrm{sgn}(d)\, \underbrace{\frac{\psi}{R^f}\left(M + |\Delta|\, \widetilde{M}\right)}_{\geq 0}, \tag{28}$$

implying $\mathrm{sgn}(d) = \mathrm{sgn}(F_t - F_t^0)$. □

B Simulation Algorithm

We model the stock price S_t as a diffusion process with stochastic volatility:

$$dS_t = S_t(r^f + \alpha)\, dt + S_t \sqrt{V_t}\, dW_t^S \tag{29}$$

$$dV_t = \kappa(\theta - V_t)\, dt + \sigma\sqrt{V_t}\, dW_t^V, \tag{30}$$

where W_t^S and W_t^V are two correlated Brownian motions with instantaneous correlation ρ.

Following Broadie, Chernov and Johannes (2007), we set the mean-reversion speed $\kappa = 0.023$, the long-term variance $\theta = 0.90$, the volatility parameter $\sigma = 0.14$, and the correlation $\rho = -0.4$ as estimated by Eraker, Johannes and Polson (2003). All of these parameters correspond to daily percentage returns. We set the annual risk-free rate r^f to 3% and the equity premium α to 5%.

For a sampled stock price path i, the call option price at maturity is simply given by the option's payoff:

$$F_T^i = \max\left(S_T^i - K, 0\right). \tag{31}$$

Given option prices in $t+1$, we calculate the time-t option prices by backward induction, as implied by Proposition 2:

$$\begin{aligned} F_t = \frac{1}{R^f}\Bigg(&\mathrm{E}_t(F_{t+1}) - \frac{\sigma_{SF}}{\sigma_S^2}\left(\mathrm{E}_t(S_{t+1}) - R^f S_t\right) + d\gamma\left(\sigma_F^2 - \frac{\sigma_{SF}^2}{\sigma_S^2}\right) \\ &+ \mathrm{sgn}(d)\psi\left(M_F + \left|\frac{\sigma_{SF}}{\sigma_S^2}\right| M_S\right)\Bigg) \end{aligned} \tag{32}$$

For this step, we need estimates for $\mathrm{E}_t(F_{t+1})$, $\mathrm{E}_t(S_{t+1})$, $\sigma_F^2 = \mathrm{var}_t(F_{t+1})$, $\sigma_S^2 = \mathrm{var}_t(S_{t+1})$, and $\sigma_{SF} = \mathrm{cov}_t(S_{t+1}, F_{t+1})$. All of these terms are in fact conditional expectations, so they can be estimated using the least square Monte Carlo method proposed by Longstaff and Schwartz (2001).

For example, we estimate $\mathrm{E}_{t,i}(F_{t+1})$ as the fitted value $\hat{F}^i_{t+1}$ from a cross-sectional regression of F_{t+1} on several time-t state variables across all sample paths:

$$F^i_{t+1} = \alpha_t + \sum_{j=1}^{n_j} \sum_{k=1}^{5} \beta^{j,k}_t y^{i,j,k}_t + \epsilon^i_{t+1} \tag{33}$$

We obtain suitable independent variables $y^{i,j,k}_t = f^k(x^{i,j}_t)$ by evaluating the first five weighted Laguerre polynomials f^k, as defined in Longstaff and Schwartz (2001), at several time-t state variables $x^{i,j}_t$. A natural choice for a state variable is the underlying stock price, $x^{i,1}_t = S^i_t$, but we also include the Black-Scholes call option price, $x^{i,2}_t = C^i_t$, as well as the respective square roots and pairwise products of these variables. The inclusion of the Black-Scholes option price increases the goodness of fit due to its similarity to the modeled option price, and being just a function of time-t variables, it is a viable choice for an additional state variable. The square root terms introduce odd powers of the stock and Black-Scholes option prices to the set of state variables, which significantly improves the estimation results.

The variances and covariances are estimated in a similar fashion. For example, $(\sigma^2_F)^i_t$ is estimated as the fitted value from a regression of $(F^i_{t+1} - \mathrm{E}_t(F^i_{t+1}))^2$ on the independent variables introduced above, using $\hat{F}^i_{t+1}$ as estimate for $\mathrm{E}_{t,i}(F_{t+1})$.

Finally, we impose several constraints on the estimates to take account of basic statistical and economical properties. For example, we require that conditional variances are positive, that the implied correlation between the stock and call option prices is always between zero and one, and that the resulting option prices are positive and less than the stock price. If an estimate violates one of these constraints, we replace the estimate with the respective boundary value.

In any case, considering a frictionless benchmark model (i.e., setting $\psi = 0$ and $\gamma = 0$), we find that the estimated option prices match theoretical option prices from the **?** model very well, which we view as justification for the chosen algorithm.

Internet Appendix for

Margin Requirements and Equity Option Returns

(not for publication)

Table IA.1: Correlation analysis

This table shows average cross-sectional correlations between expensiveness, option margins, hedging capital, moneyness and time to maturity. All values are given in percent.

Panel A: Call options

		(2)	(3)	(4)	(5)
(1)	Expensiveness	−4	−12	22	−10
(2)	Option margin		64	−27	−19
(3)	Hedging capital			−28	−44
(4)	Moneyness				4
(5)	Time to maturity				

Panel B: Put options

		(2)	(3)	(4)	(5)
(1)	Expensiveness	3	1	−7	−10
(2)	Option margin		95	−34	−38
(3)	Hedging capital			−34	−47
(4)	Moneyness				11
(5)	Time to maturity				

Table IA.2: Fama-MacBeth regressions (Call options)

This table reports Fama-MacBeth regression results of monthly delta-hedged option returns, based on the sample of all call options. Dependent variables are the options' margin and hedging capital requirements. We estimate segmented regression coefficients based on expensiveness quintiles, which are formed at the beginning of each month. Below, *option margin (k)* and *hedging capital (k)* refer to the respective margin variable for options within the k-th expensiveness quintile. Control variables on the option level are the relative bid-ask spread, the logarithm of the option's open interest, delta, gamma, vega, as well as time to maturity in days. In addition, we include a GARCH estimate of the underlying stock's historical volatility, its systematic risk proportion, as well as the firms' size and balance sheet leverage. All coefficients are given in percent, significances are based on Newey-West standard errors with 4 lags.

Model	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Option margin (1)	0.69***		0.76***		0.12	0.19
Option margin (2)	0.12		0.17*		−0.10	−0.02
Option margin (3)	−0.26***		−0.22***		−0.31***	−0.21**
Option margin (4)	−0.59***		−0.55***		−0.42***	−0.29***
Option margin (5)	−1.09***		−1.04***		−0.51***	−0.36***
Hedging capital (1)		1.00***		1.14***	1.03***	1.05***
Hedging capital (2)		−0.11		−0.14	0.21	0.07
Hedging capital (3)		−0.78***		−0.92***	−0.21	−0.48**
Hedging capital (4)		−1.51***		−1.74***	−0.84***	−1.23***
Hedging capital (5)		−2.87***		−3.22***	−2.01***	−2.53***
Log(open interest)			−0.20***	−0.22***		−0.21***
Delta			3.31*	3.63*		3.19*
Time to maturity			0.01**	0.00		0.00
Gamma			2.54	10.35**		4.98
Vega			0.04***	0.06***		0.03**
Stock volatility			−0.43***	−1.14***		−1.03***
Systematic risk			0.94	0.47		0.18
Firm size			0.07	0.16		0.17
Firm leverage			0.49	1.06		0.93
Constant	0.03	2.14***	−3.04	0.61	1.43***	−0.02
Average R^2	0.04	0.04	0.07	0.07	0.05	0.08

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Table IA.3: Fama-MacBeth regressions (Put options)

This table reports Fama-MacBeth regression results of monthly delta-hedged option returns, based on the sample of all put options with an ex-ante delta of at most −0.2. Dependent variables are the options' margin and hedging capital requirements. We estimate segmented regression coefficients based on expensiveness quintiles, which are formed at the beginning of each month. Below, *option margin (k)* and *hedging capital (k)* refer to the respective margin variable for options within the k-th expensiveness quintile. Control variables on the option level are the relative bid-ask spread, the logarithm of the option's open interest, delta, gamma, vega, as well as time to maturity in days. In addition, we include a GARCH estimate of the underlying stock's historical volatility, its systematic risk proportion, as well as the firms' size and balance sheet leverage. All coefficients are given in percent, significances are based on Newey-West standard errors with 4 lags.

Model	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Option margin (1)	1.46***		1.42***		0.49	−0.06
Option margin (2)	0.92***		0.73***		0.68	−0.04
Option margin (3)	0.39		0.17		0.31	−0.27
Option margin (4)	−0.14		−0.38**		0.09	−0.41**
Option margin (5)	−1.54***		−1.74***		0.07	−0.54**
Hedging capital (1)		1.24***		1.19***	0.81***	1.30***
Hedging capital (2)		0.74***		0.58***	0.18	0.66***
Hedging capital (3)		0.31		0.10	0.07	0.39*
Hedging capital (4)		−0.15		−0.38**	−0.22	0.02
Hedging capital (5)		−1.39***		−1.59***	−1.46***	−1.10***
Log(open interest)			−0.21***	−0.20***		−0.20***
Delta			3.00*	3.35*		3.39*
Time to maturity			0.00*	0.00*		0.01*
Gamma			−2.00	−2.08		−2.22
Vega			−0.01	0.00		0.00
Stock volatility			−0.38***	−0.46***		−0.44***
Systematic risk			2.63***	2.51***		2.54***
Firm size			0.26***	0.23***		0.22***
Firm leverage			0.22	0.32		0.33
Constant	0.29	0.31	−3.32*	−2.07	0.35	−2.19
Average R^2	0.06	0.05	0.09	0.09	0.06	0.09

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Table IA.4: Portfolio sorts conditional on the level of funding costs (Put options)

This table shows long-short returns of put option quintile portfolios formed on option margins and hedging capital, respectively, for different levels of funding costs. We split our sample in periods of low and high funding costs based on a median-split of the TED spread. In each subsample, we run monthly double sorts on option expensiveness and the respective margin variable, and calculate long-short returns in the margin dimension. We report time-series averages with Newey and West (1987) significance levels using 4 lags. All returns are given in monthly percent.

Panel A: TED spread median-split

		Option margin long-short		Hedging capital long-short	
Funding costs		low	high	low	high
Expensiveness	1 (low)	−0.06	3.86***	−0.08	3.64***
	2	−0.62	3.53***	−0.35	2.81**
	3	−1.12	2.93**	−1.22	2.38*
	4	−1.92*	1.96	−2.00**	1.00
	5 (high)	−4.54***	−1.92	−4.32***	−1.80
	5–1	−4.49***	−5.78***	−4.24***	−5.44***

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Panel B: Broker-Dealer leverage median-split

		Option margin long-short		Hedging capital long-short	
Funding costs		low	high	low	high
Expensiveness	1 (low)	−0.02	3.76***	0.35	3.16***
	2	−0.83	3.67***	−0.55	2.94***
	3	−1.42	3.15**	−1.31	2.40**
	4	−2.16	2.12	−2.21*	1.14
	5 (high)	−4.98***	−1.55	−4.63***	−1.55
	5–1	−4.96***	−5.31***	−4.97***	−4.71***

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Table IA.5: Coverage of ISE demand data

This table shows the number of stocks and options per year, as well as options per stock-month in different datasets. The first column corresponds to our baseline dataset, the second to a restricted dataset starting in 2005. Results for the joint dataset containing the additional trading volumes from the ISE Open/Close Trade Profile data are shown in the third column.

	Base (1996)	Base (2005)	ISE merged (2005)
Stocks per year	2 416	2 802	1 709
Options per year	204 398	250 419	174 880
Options per stock-month	22	25	24

Table IA.6: Further robustness checks on conditional margin long-short returns

This table shows several robustness checks on the conditional margin long-short returns given in Table 3. The first column shows analogous long-short returns for all options, i.e., without any filter on delta. The second column is also based on the full cross-section of options, but removing options-months containig daily option returns of more than 1 000%. In the third column, we repeat the original analysis using equally weighted portfolios. The fourth column shows results for another expensiveness measures, where we used a 60 day window to calculate the historical baseline volatility. We also report margin long-short returns for options on SPX index members, and alphas with respect to the betting against beta (BAB) factor of Frazzini and Pedersen (2012). Significances are based on Newey and West (1987) standard errors with 4 lags.

Panel A: Call Options

		All	All (filtered)	Equal weights	IVHV(60)	SPX members	BAB alpha
Expensiveness	1	1.61	0.89	7.40***	0.78	0.17	1.99
	2	−1.93	−2.62	−0.31	−2.16	−2.25	−1.53
	3	−3.65**	−3.85**	−5.17***	−3.51**	−5.64***	−3.16*
	4	−6.14***	−6.53***	−10.06***	−5.54***	−5.85***	−5.77***
	5	−11.65***	−11.91***	−17.67***	−9.54***	−10.95***	−10.80***
	5–1	−13.26***	−12.80***	−25.06***	−10.32***	−11.12***	−12.79***

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Panel B: Put Options

		All	All (filtered)	Equal weights	IVHV(60)	SPX members	BAB alpha
Expensiveness	1	3.46**	3.30**	4.75***	1.76*	1.86*	2.03**
	2	3.18**	3.05*	2.85***	1.55	1.61	1.75*
	3	2.33	1.81	1.17	0.64	1.18	1.18
	4	0.39	−0.46	−0.23	−0.21	−0.79	0.30
	5	0.58	−3.61	−4.37***	−2.35**	−3.44**	−2.68**
	5–1	−2.88	−6.91***	−9.12***	−4.10***	−5.29***	−4.71***

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$