Fundamentals Still Matter: The Determinants of Equity Option Returns *

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Abstract

This paper studies the determinants of the delta-hedged equity option returns both theoretically and empirically. Under a Merton-type structural model with double-exponential jump diffusion process, the expected return of delta-hedged equity option portfolio is determined by two firm-level variables: financial leverage and asset volatility of the firm. The result suggests that the determinants affect positive and negative delta-hedged option returns differently and it is important to take into account the higher order polynomials of the determinants. Empirically, we find that these two structural variables can explain a large portion of the cross-sectional variation in the data and even subsume information in other determinants documented in the literature, such as idiosyncratic volatility and liquidity. The results from the double sorting portfolios are consistent with the theoretical implications. The empirical evidence also supports the nonlinear relation between the determinants and the delta-hedged equity option returns. These findings are robust across calls, puts and different moneyness levels.

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1 Introduction

The notion that options are not redundant assets has been widely accepted in financial economics (e.g. Buraschi and Jackwerth (2001) and Jones (2006)). In the past two decades, the equity option market in the United States has experienced exponentially growth . Figure 1 shows that the average daily trading volume (open interest) of equity options has increased from 0.79 (18.23) million in 1996 to 14.81 (263.57) million in 2015. In light of the tremendous growth in this market, understanding the determinants of the equity option returns becomes increasingly relevant. Recent studies find that several factors are related to the equity option returns, e.g., the difference between historical realized volatility and at-the-money implied volatility (Goyal and Saretto (2009)), idiosyncratic volatility of the underlying stock (Cao and Han (2013)), option illiquidity (Christoffersen et al. (2014)) and volatility term structure (Vasquez (Forthcoming)). In addition to these market-based factors, how does variables suggested in the Merton-type structural model determine the equity option returns? Do they play an additional, or even a more fundamental role in explaining the cross-sectional variation of the equity option return? To answer these questions, this paper aims to identify the determinants of equity option returns from the structural model, and then investigate the explanatory power of these determinants using cross-sectional equity option data in the US market.

In this paper, we consider the delta-hedged equity option portfolio, consisting of a long option position, dynamically delta-hedged by a short position in the stock, such that the portfolio is not sensitive to the small movements in the underlying stock. The portfolio is not exposed to risks except for variance risk and jump risk. Bakshi and Kapadia (2003) show that the sign and magnitude of this portfolio return are closely related to the variance risk premium. While much of the existing knowledge about the variance risk premium is based on the index options, e.g. Bakshi and Kapadia (2003), Todorov (2010) and Bollerslev et al. (2009), the variance risk premium of the individual stocks is less well understood. A natural question is, which firm characteristics are related to the variance risk premium of the individual stocks? Structural models following Merton (1974) imply that all contingent claims written on a single firm's asset or cash flow should be priced according to the same source of risk factor. Hence, the theoretical determinants that affect equity risk or credit risk of the firm, such as financial leverage and asset volatility, may also affect higher order risk premium of the stock, i.e. the variance risk premium.

Consider two firms with the same asset processes, but different leverage ratios. They are both exposed to the market volatility risk and/or market jump risk. The firm with higher leverage ratio is more exposed to the market volatility and market jump risk, and has a higher default probability than the firm with lower leverage ratio. If the price of volatility risk and jump risk is negative, as suggested Bakshi and Kapadia (2003) and Carr and Wu (2009), the delta-hedged option returns should on average be negative and more negative for the firm with higher leverage ratio.

To formalize the idea, we derive the expected return of a delta-hedged option portfolio based on the capital structure model developed by Chen and Kou (2009). In this model, the dynamic of the asset value of a firm follows a double-exponential jump diffusion process. The firm's capital structure consists of equity and perpetual debt with constant coupon payments. When the asset value hits a certain threshold, the firm declares bankruptcy. Based on this framework, we find that the expected return of delta-hedged equity option portfolio relates to several firm-level structural variables: the variance of the jump component in the asset process, the leverage ratio of the firm and the level of bankruptcy trigger. The result implies, after dynamically hedging out the option exposure to the underlying stocks, the portfolio return is still driven by the determinants of the stock returns. The reason is that, due to the exposure to variance risk or jump risk, the effect of the firms' characteristics on the stock returns is inherited to the variance risk premium of the firm. Furthermore, simulations of the model show that the relation between the determinants and the portfolio returns is nonlinear. This implies that it is important to take into account the higher order polynomials of the determinants when we analyze the relation between the theoretical determinants and the expected return of the delta-hedged option portfolios.

There are two common sources of variance risk: the presence of stochastic volatility and the occurrence of unanticipated jumps. We use the jump diffusion-type of model instead of the stochastic volatility model for several reasons. First, the two types of models explain the expected delta-hedged return in different channels, but with similar implications. In both models, there is one extra stochastic component which cannot be hedged away by delta hedging. Disentangling the two sources is less important when we focus on the relation between the theoretical determinants and the variance risk premium of the individual stocks. Second, Todorov (2010) finds that jumps play a very important role in explaining the dynamics of variance risk premium. Third, a closed form for the equity value of the firm is only possible under the jump diffusion model when the jump size follows an exponential distribution. The explicit form of joint distribution of default time and default trigger is not available under the stochastic volatility model.

To study the variance risk premium of the individual stocks, we use the delta-hedged option returns, instead of a more direct measure: the difference between the realized variance and the implied variance. First, due to liquidity reason, the available number of equity options for a firm is usually less than six in one day. Zhou and Xiao (2015) shows that the approximation error of the risk neutral variance can be huge when the number options is limited. The delta-hedged option portfolio only requires only one option for each stock on the same day. Second, it is easier to implement trading strategies using delta-hedged equity option portfolios, rather than trading directly on the variance risk premium of the individual stocks.

To test the implications of the model, we examine cross-section of equity option returns in the US market. We pick one call (or put) option on each optionable stock that has a maturity about one month and evaluate the return of the portfolio that buys one call (or put) and daily delta-hedges with the underlying stock. The empirical results are supportive of the model implications. First, the delta-neutral strategy that buys equity options and hedges with the underlying stock significantly underperforms zero. On average, the strategy loses about 1.97% of the starting value of the portfolio. Second, after controlling for other firm characteristics such as firm size, the delta-hedged option return is decreasing with leverage ratio and asset volatility. The result of double sorting portfolios based on asset volatility and leverage ratio shows that the returns from quintile 1 to quintile 5 along both sorting criteria exhibit monotonic trend, which is consistent with the theory. Third, using short-term debt ratio as a proxy of the level of the bankruptcy trigger, we find that the delta-hedged option portfolios in firms with higher short-term debt ratio exhibit significantly more negative returns than those of firms with mainly long-term debt financing. Fourth, we find evidence of the nonlinear relationship between the two determinants and the delta-hedged option returns. The coefficients of the higher order polynomials of the determinants are statistically significant in explaining the cross-sectional variation of delta-hedged option returns.

This paper contributes to several strands of the literature. First, it adds to a growing literature that studies the cross section of delta-hedged equity option returns. Previous papers have identified several market-based factors that affect the delta-hedged return in the cross section of equity options[1]. Most results from this literature are motivated by volatility-related option mispricing and option liquidity. However, how the underlying firm's characteristics affect the delta-hedged option return have not attracted sufficient attention. My paper departs from these papers along several dimensions. First, my findings augment the literature by showing that the financing decision of the firm plays a sizable role in generating cross-section variations in delta-hedged equity option returns. To the best of my knowledge, this paper is the first one to identify theoretical determinants of delta-hedged equity option returns or the equity variance risk premium. Second, compared with the empirical research in this field, this paper provides a framework to explain the proposed relation, such that the interaction of the different structural parameters and the delta-hedged gain can be understood in a structural model. Third, the results of the existing research generally cannot be explained by usual risk factor models, whereas the theoretical model and the empirical results in this paper are in general consistent within a risk-based framework.

Second, this paper contributes to the literature on the impact of leverage on the prices or returns of different assets. The notion that equity is a call option on the firm's asset goes back to Merton (1974). Following this philosophy, Geske (1979) models equity options as compound options on firm's asset, but the firm is not allowed to declare bankruptcy before the debt matures. Toft and Prucyk (1997) propose an equity option pricing model that allows for taxes and bankruptcy and show that firm's leverage and debt covenants affect option values and implied volatility skew. Ericsson et al. (2009) show empirical evidence that leverage and volatility are important determinants of credit default swap premia. More recently, Geske

[1] See Goyal and Saretto (2009), Cao and Han (2013), Vasquez (Forthcoming) and Christoffersen et al. (2014).

et al. (2014) study the impact of leverage on the pricing of equity options. They find that considering the leverage reduces the pricing errors by 20% on average, compared to Black-Scholes model. The models in these papers only assume one dimension of randomness in the undelying asset. Hence, they cannot explain the negative delta-hedged option returns, because Bakshi and Kapadia (2003) show that if the underlying price process follows a one-dimensional Markov diffusion, then the delta-hedged gain is precisely zero. The model in this paper differs from this stream of literature in that there are two independent randomnesses in the underlying asset process, such that the delta-hedged gain of the equity option portfolio is not zero.

Finally, this paper is related to two recent papers that study variance risk premium in the cross-section of equity options. Vedolin (2012) provides a theoretical framework to explain the volatility risk premia using a Lucas tree model with heterogeneous beliefs, stochastic macro-economic uncertainty and default risk. My paper differs from this one in several aspects. First, the model in my paper focuses more on the role of firm's capital structure. It allows firm to declare bankruptcy before the maturity of the corporate bond, and the equity holder to determine the bankruptcy trigger endogenously by maximizing the firm value. Second, we investigate the role of nonlinear relationship between leverage and variance risk premium, which helps to explain the cross-sectional variation of the variance risk premium to a large extent. Third, we construct the delta-hedged option portfolio to capture the volatility risk premia, in which the relation between leverage and volatility risk premia can be translated to trading strategies. The idea of my paper is also close to González-Urteaga and Rubio (Forthcoming), who find that the market volatility risk premium and the default premium are key determinants risk factors in the cross-sectional variation of average volatility risk premium. However, they consider a representative set of portfolios rather than the equity options on the individual stocks. The focus of my paper is different from theirs.

The remainder of the paper is organized as follows. Section 2 presents the capital structure model, develops and interprets the pricing formulas for options on levered equity. Section 3 describes the data and the summary statistics. Section 4 presents empirical results of double sorting portfolios and cross-sectional multivariate regressions that control for various firm-specific variables including size, idiosyncratic volatility and liquidity. It also investigates time series properties of delta-hedged option returns.

2 Pricing Options on leveraged equity with endogenous default and jump risk

This section describes the pricing of options on leveraged equity. The relevant theory is developed based on a two-sided jump model for credit risk proposed by Chen and Kou (2009), which can accommodate optimal capital structure, credit spread and implied volatility in a unified framework. Compared with Merton (1974)'s original work, this model has two advantages. First, it allows a firm to declare bankruptcy before the maturity of the bond and the shareholders can choose the optimal bankruptcy trigger endogenously. Second, it introduces two independent randomnesses in the underlying asset process. Chen and Kou (2009) show that the model is capable of generating realistic level of credit spread, optimal leverage ratio and different shapes of implied volatility smile. This model is able to deliver the explicit expression of expected delta-hedged option returns based on a capital structure model, while preserving much of the richness to explore different features in the firm's debt structure.

In Section 2.1 and Section 2.2, we present a simplified version of Chen and Kou (2009)'s model to price the equity value of the firm. Then, the expected return of the delta-hedged equity option portfolio is derived in Section 2.3. The intuition of the propositions and numerical examples are provided in Section 2.4 and Section 2.5. The implications of the model are then used to motivate the empirical analysis.

2.1 Asset model

Consider a firm whose asset value V_t follows a double exponential jump-diffusion process under the physical measure,

$$\frac{dV_t}{V_t^-} = \mu dt + \sigma dW_t + d(\sum_{i=1}^{N_t}(J_i - 1)), \tag{1}$$

where $dW_t = \rho\, dW_{1t} + \sqrt{1-\rho^2} dW_{2t},\ \rho \in [0,1),\ W_t^1$ and W_t^2 are independent standard Brownian processes, $\{N_t, t \geq 0\}$ is a Poisson process with jump intensity λ and and $\{J_i\}$ is a sequence of independent identically distributed nonnegative random variables such that $Y = \ln(J)$ has a double-exponential density,

$$f_Y(y) = p_u \eta_u e^{-\eta_u y} \mathbb{1}_{y \geq 0} + p_d \eta_d e^{\eta_d y} \mathbb{1}_{y<0},\ \eta_u > 1, \eta_d > 1, p_u + p_d = 1.$$

To be more specific, Y has a mixed distribution:

$$Y = \begin{cases} x^+ & \text{with probability } p_u \\ -x^- & \text{with probability } p_d. \end{cases}$$

where x^+ and x^- are exponential random variables with means $\frac{1}{\eta_u}$ and $\frac{1}{\eta_d}$.

The solution of the stochastic differential equation in(1) is given by,

$$V_t = V_0 exp((\mu - \frac{1}{2}\sigma^2)t + \sigma W_t) \prod_{i=1}^{N_t} J_i.$$

To derive the delta-hedged option gain, we need to use the physical distribution of the asset value to derive the stock price process under the physical measure, and to use the risk neutral process of the asset value to derive the value of option on levered equity. Due to the jumps, the risk-neutral probability measure is not unique. In a typical rational expectations economy as in Kou (2002), a representative investor maximizes a utility function of the consumption process c_t. Consider the utility function of the special form $U(c_t) = \frac{c_t^\alpha}{\alpha}$ if $0 < \alpha < 1$ and $U(c_t) = \log(c_t)$ if $\alpha = 0$. It can be shown that, when the consumption process follows the jump diffusion process in equation 2, the equilibrium price of a derivative on this asset is given by the discounted expectation of the payoff under the risk neutral measure:

$$\frac{dc_t}{c_t} = \mu_1 dt + \sigma_1 dW_{1t} + d(\sum_{i=1}^{N_t}(J_i - 1)), \tag{2}$$

where the jump component is the same as the one in the asset process of the firm and all three randomnesses are independent. The implication is that the systematic jump and diffusion risks are priced in the asset returns. More generalized results can be obtained if we assume that the jump component in the asset process has an idiosyncratic part which is not correlation with the pricing kernel. Here we focus on the simplistic model setup.

The risk neutral measure is defined as: $dQ/dP = Z_t/Z_0$, where $Z_t = e^{rt}c_t^{\alpha-1}$. The asset model in (1) satisfies equilibrium requirement if and only if,

$$\mu = r + \sigma_1\sigma\rho(1-\alpha) - \lambda(\xi^{(\alpha)} - \xi^{(\alpha-1)}), \tag{3}$$

where $\xi^{(\alpha-1)}$ is given by

$$\xi^{(\alpha)} = E[J^\alpha - 1] = E[e^{Y(\alpha)} - 1] = \frac{p_u\eta_u}{\eta_u - \alpha} + \frac{p_d\eta_d}{\eta_d + \alpha} - 1. \tag{4}$$

If the drift term of V_t under the physical measure satisfies (3), then under the risk neutral measure Q, the asset value of the firm follows:

$$\frac{dV_t}{V_t^-} = (r - \lambda^Q(E^Q(J_i - 1)))dt + \sigma dW^Q + d(\sum_{i=1}^{N_t^Q}(J_i^Q - 1)), \tag{5}$$

where W_t^Q is a new Brownian motion under Q, N_t^Q is a new Poisson process with jump intensity $\lambda^Q = \lambda(\xi^{(\alpha-1)} + 1)$ and $\{J_i^Q\}$ are independent identically distributed random variables with a new density under Q:

$$f_J^Q(x) = \frac{1}{1 + \xi^{(\alpha-1)}} x^{\alpha-1} f_J(x). \tag{6}$$

2.2 Debt, equity and market value of the firm

The firm pays a nonnegative coupon, c, per instant of time when the firm is solvent. Let V_B denote the level of asset value at which bankruptcy is declared. The bankruptcy occurs at time $\tau = inf\{t \geq 0 : V_t \leq V_B\}$. Upon default, the firm loses $1 - \alpha_d$ of V_τ, leaving debt holders with value $\alpha_d V_\tau$ and stockholders with nothing. Note that V_τ may not be equal to V_B due to jumps.

To compute the total debt and equity values, one needs to compute the distribution of the default time τ and the joint distribution of V_τ and τ. Kou and Wang (2003) show that the analytical solutions for these distributions depend on the roots of the following equation:

$$r = -(r - \frac{1}{2}\sigma^2 - \lambda\xi)x + \frac{1}{2}\sigma^2 x^2 + \lambda(\frac{p_u \eta_u}{\eta_u - x} + \frac{p_d \eta_d}{\eta_d + x} - 1),$$

which has exactly four roots γ_1, γ_2, $-\gamma_3$ and $-\gamma_4$, with

$$0 < \gamma_1 < \eta_d < \gamma_2, \;\; 0 < \gamma_3 < \eta_u < \gamma_4.$$

Based on the distribution of default time and the joint distribution of default threshold and default time, the value of total asset, debt and equity value of the firm can then be obtained. The total market value of the firm is the firm asset value plus the tax benefit and minus the bankruptcy cost, which depend on the asset value of the firm V and the bankruptcy threshold V_B:

$$\begin{aligned} v(V, V_B) &= V + E[\int_0^\tau \kappa\rho P e^{-rt} dt] - (1 - \alpha_d) E[V_\tau e^{-r\tau}] \\ &= V + \frac{\kappa c}{r}(1 - d_1(\frac{V_B}{V})^{\gamma_1} - d_2(\frac{V_B}{V})^{\gamma_2}) - (1 - \alpha_d) V_B (c_1(\frac{V_B}{V})^{\gamma_1} + c_2(\frac{V_B}{V})^{\gamma_2}), \end{aligned}$$

where $c_1 = \frac{\eta_d - \gamma_1}{\gamma_2 - \gamma_1}\frac{\gamma_2 + 1}{\eta_d + 1}$, $c_2 = \frac{\gamma_2 - \eta_d}{\gamma_2 - \gamma_1}\frac{\gamma_1 + 1}{\eta_d + 1}$, $d_1 = \frac{\eta_d - \gamma_1}{\gamma_2 - \gamma_1}\frac{\gamma_2}{\eta_d}$, and $d_2 = \frac{\gamma_2 - \eta_d}{\gamma_2 - \gamma_1}\frac{\gamma_1}{\eta_d}$. The value of total debt at time 0 is the sum of the expected coupon payment before bankruptcy and the expected payoff upon bankruptcy:

$$\begin{aligned} D(V; V_B) &= E[\int_0^\tau e^{-rt} c dt + \alpha_d e^{-r\tau} V_\tau] \\ &= \frac{c}{r}(1 - d_1(\frac{V_B}{V})^{\gamma_1} - d_2(\frac{V_B}{V})^{\gamma_2}) + \alpha_d V_B (c_1(\frac{V_B}{V})^{\gamma_1} + c_2(\frac{V_B}{V})^{\gamma_2}), \end{aligned}$$

The total equity value is the difference between the total asset value and the total debt value,

$$S(V; V_B) = v(V; V_B) - D(V; V_B) \tag{7}$$

$$= V + aV^{-\gamma_1} + bV^{-\gamma_2} - \frac{(1 - \kappa)c}{r}, \tag{8}$$

where $a = \frac{(1-\kappa)cd_1}{r} V_B^{\gamma_1} - c_1 V_B^{\gamma_1+1}$ and $b = \frac{(1-\kappa)cd_2}{r} V_B^{\gamma_2} - c_2 V_B^{\gamma_2+1}$.

The bankruptcy trigger V_B is either exogenously given by a net worth covenant, i.e. a covenant triggers bankruptcy when the asset value hits the threshold $V_B = \frac{c}{r\alpha_d}$, where α_d is the portion of asset value the debt holders can get upon default. The bankruptcy trigger can also be determined endogenously if it is within the equity holder's discretion to declare banktuptcy. For a fixed coupon level c, Chen and Kou (2009) derived the optimal choice of V_B^* by maximizing the total equity values:

$$V_B^* = \frac{\epsilon c}{r}, \text{ where } \epsilon = \frac{(1-\kappa)(d_1\gamma_1 + d_2\gamma_2)}{c_1\gamma_1 + c_2\gamma_2 + 1}. \tag{9}$$

Whether the default trigger is determined exogenously (protected debt) or endogenously (unprotected debt) has impact on the pricing of the firm's equity value, and furthermore on the pricing of options on the firm's levered equity. Empirically, it is possible to use balance sheet data to approximate the protective net-worth covenant. For instance, the term structure of the firm's debt can be used as a proxy for the existence of net worth hurdle. Leland (1994) shows that the short term debt can be associated with an exogenous bankruptcy triger that equals the market value of debt on the issue date. Long term debt results in an endogenous trigger which is significantly below the previous one. This implies that a firm with a large portion of long-term debt due in the immediate future faces a net-worth hurdle, Otherwise they are not able to renew the credit line.

2.3 Delta-hedged returns of options on the levered equity

In this subsection, we turn to the valuation of options written on the levered equity and the derivation of delta-hedged option returns. The value of an European option wittern on equity $S(V;V_B)$ at time 0 maturing at t, with strike price K can be expressed as:

$$O(0,t;K) = e^{-rt} E^Q[\text{Payoff} \times 1_{\tau \geq t}],$$

where τ is the stopping time when asset value of the firm hits the bankruptcy trigger the first time and Q represents the risk neutral measure. The payoff for the call options at maturity is $\max(S_t(V_t; V_B) - K, 0)$ and $\max(K - S_t(V_t; V_B), 0)$ for the put options.

To remove the impact of the underlying stock movement on the option returns, we consider the return on a portfolio of a long position in an option, hedged by a short position in the underlying stock, such that the portfolio is not sensitive to the movement of the underlying stock prices. The delta-hedged gains, $\Pi_{0,t}$, is defined as the gain or loss on a delta-hedged option position, subtract the risk free rate earned by the portfolio:

$$\Pi_{0,t} = O_t - O_0 - \int_0^t \Delta_u dS_u - \int_0^t r(O_u - \Delta_u S_u) du,$$

where $\Delta_t = \frac{\partial O_t}{\partial S_t}$, r is the constant risk free rate. By Ito's lemma, under the physical distribution, the option price can be written as,

$$O_t = O_0 + \int_0^t \frac{\partial O}{\partial u} du + \int_0^t \frac{\partial O_u}{\partial S_u} dS_u^c + \frac{1}{2} \int_0^t \frac{\partial^2 O_u}{\partial S_u^2} dS_u^c dS_u^c + \sum_{0<u<t} (O(S_u) - O(S_{u-})). \quad (10)$$

where dS_u^c is the continuous part of dS_u. The last part in equation (10) sums up the movement of the option price due to the discontinuous jumps from time 0 to t. $O(S_u)$ is the option price evaluated at S_u which is the stock price immediately after a jump and $O(S_{u-})$ is the option price evaluated just before the jump.

Since the equity value is a function of the asset value given by equation (8), the stochastic process of the equity value can also be obtained by Ito's lemma:

$$dS = \frac{\partial S}{\partial V} dV^c + \frac{1}{2} \frac{\partial^2 S}{\partial V^2} \sigma^2 V^2 dt + d \sum_{i=1}^{N} (S(V) - S(V_-)),$$

where $S(V) - S(V_-) = (VJ_i + a(VJ_i)^{-\gamma_1} + b(VJ_i)^{-\gamma_2}) - (V + aV^{-\gamma_1} + bV^{-\gamma_2})$. The subscripts of S and V are ignored for simplicity.

Under the risk neutral measure Q, the process of the equity value can be rewritten as,

$$dS^Q = \mu_S^Q dt + \sigma_S^Q dW_t^Q + d \sum_{i=1}^{N^Q} (S(V) - S(V_-)),$$

On one hand, we can obtain μ_S^Q and σ_S^Q by substituting the risk neutral process of V_t, and then $\mu_S^Q = (r - \lambda^Q(E^Q(J_i - 1)))\frac{\partial S}{\partial V}V_t + \frac{1}{2}\frac{\partial^2 S}{\partial V^2}\sigma^2 V_t^2$, $\sigma_S^Q = \sigma V_t \frac{\partial S}{\partial V}$. On the other hand, since equity value is a convex function of the asset value, the discounted equity price process should be a martigale under the risk neutral measure. Hence, $\mu_S^Q = rS - \lambda^Q E^Q[S(V) - S(V-)]$. The discounted option price process $e^{-rt}O_t$ is also a martingale under Q, the integro-partial differential equation of the option price O_t is:

$$rO_t = \frac{\partial O}{\partial t} + \frac{\partial O}{\partial S}\mu_S^Q + \frac{1}{2}\frac{\partial^2 O}{\partial S^2}(\sigma_S^Q)^2 + \lambda^Q E^Q[O(S) - O(S_-)]. \tag{11}$$

Combining equations (10) and (11), the option price can be rewritten as,

$$O_t = O_0 + \int_0^t \frac{\partial O}{\partial S} dS^c + \int_0^t (rO - \frac{\partial O}{\partial S}\mu_S^Q - \lambda^Q E^Q[O(S) - O(S_-)])dt + \sum_{0<u<t}(O(S_u) - O(S_{u-})).$$

Therefore, the expected delta-hedged gain is equal to:

$$\begin{aligned} E(\Pi_t) &= E(O_t - O_0 - \int_0^t \frac{\partial O}{\partial S} dS_u - \int_0^t r(O - \frac{\partial O}{\partial S} S du)) \\ &= \int_0^t \{-\lambda^Q E^Q[O(S) - O(S_-)] + \lambda^Q E^Q[(S(V) - S(V_-))\frac{\partial O}{\partial S}] \\ &- \lambda E[(S(V) - S(V_-))\frac{\partial O}{\partial S}] + \lambda E[O(S) - O(S_-)]\}dt. \end{aligned} \tag{12}$$

The following proposition shows the relation between delta-hedged gains, the jump risk premium, and the option gamma. The proof of Proposition 1 is provided in Appendix A.1.

Proposition 1 *Let the firm's asset price process under the physical and risk neutral measures follows the dynamics given in Equations (1) and (5), and the equity value of the firm is given by Equation (8). Then, the expected delta-hedged gain is given by,*

$$E(\Pi_t) \approx \int_0^t \frac{1}{2}\frac{\partial^2 O_u}{\partial S_u^2}(\frac{\partial S_u}{\partial V_u})^2(\lambda E[V_u - V_{u-}]^2 - \lambda^Q E^Q[V_u - V_{u-}]^2)du. \tag{13}$$

where $\frac{\partial^2 O}{\partial S^2}$ *represents the gamma of the option,* $E[.]$ *is the expectation operator under the physical measure, and* $E^Q[.]$ *is the expectation operator under the risk neutral measure.*

The expected delta-hedged gain $E(\Pi_t)$ *is negative, if and only if* $\frac{p_u}{\eta_u^3} - \frac{p_d}{\eta_d^3} < 0$*. One sufficient but not necessary condition is that the absolute value of the negative jump size is larger than* *the positive jump size on average,* $1/\eta_d > 1/\eta_u$*, and the expected jump size is less than zero:* $E[Y] = \frac{p_u}{\eta_u} - \frac{p_d}{\eta_d} < 0$.

The proposition states that, with continuous trading, the expected delta-hedged gain is negative provided that the jump size is on average negative, and there are occasionally price discontinuities ($\lambda > 0$). The results hold for both call options and put options. The intuition will be explained in more details in Section 2.4. The expected gain is positively correlated with option gamma, the second order derivarive of the option price over the underlying stock price. For the options with the same underlying asset, this suggests that the expected delta-hedged gain is the most negative for at-the-money options. Following the proof procedure of Proposition 1 in Appendix A.1, we have the following proposition on the relation between delta-hedged gain and financial leverage of the firm (Proof in A.2):

Proposition 2 *(1) For options with the same gamma* ($\frac{\partial^2 O}{\partial S^2}$) *and asset value* ($V$) *, the absolute value of the scaled delta-hedged gain* $E(\Pi_t)/S^2$ *depends on firm's debt level (c), tax rate* (τ)*, and variance of the jump component in the asset process* ($\lambda E[J-1]^2$) *and risk aversion coefficient of the representative investor* (γ)*.*

(2) The firm specific determinants: debt level and volatility of the jump component in the asset process have an amplification effect on $E(\Pi_t)/S^2$*. The effect is not linear:*$E(\Pi_t)/S^2$ *is increasing in the determinants when it is positive; decreasing in the determinants when it is negative.*

(3) The absolute value of $E(\Pi_t)/S^2$ *is larger for a firm with bankruptcy trigger exogenously determined by the net-worth covenants than that in a firm with bankruptcy trigger endogenously determined by the equity holders.*

2.4 Intuitions behind the Propositions

The expected delta-hedged gain can be understood in the framework of stochastic volatility model, or jump diffusion model. Bakshi and Kapadia (2003) argue that when volatility is stochastic and volatility risk is priced, in other words, the stochastic volatility is correlated with the pricing kernel, the expected delta-hedged gain is negative because investors are willing to pay a premium to hedge against the unfavorable volatility movement. Alternatively, the sign and magnitude of average delta-hedged gains can be explained by the jump diffusion model.

Note that the call option price is a strictly convex function of the underlying stock price. Consider an at-the-money call option at t_0, the option price is C_0. The underlying stock price and the strike price are both 100. If the stock price suffers a negative jump at t_1 from 100 to 92, then the option price drops from C_0 to C_1. However, the positive gain of the delta-hedge position $-\frac{\partial C_0}{\partial S_0}(S_1 - S_0)$ exceeds the loss in the option value, because option price is a convex function of the underlying price. Similarly, after positive jumps, the gain of the delta-hedged call option is positive. If the stock price change is small enough, and the stock return can be approximated as a diffusion process, then the gain of delta-hedged option position should be zero on average. However, if we assume that discontinuous jumps occur sometimes in the stock return, then the movement of stock return cannot be hedged out completely. The second order derivative of the option price over the underlying stock price leaves us with the gamma risk.

The reasoning can also be applied to the put options. Therefore, the delta-hedged gains for call and put option are both positive after unexpected jumps. If the negative jumps in the stock prices are more frequent than the positive ones, and if the average absolute size of negative jumps is larger than the positive ones, the gain of delta-hedged option position is then negatively related to the underlying stock return. Usually, the stock returns comove with the market return in the same direction, so the expected gain of the delta-hedged option position is negative, as the investors pay a premium to hedge against the undesired jump risk.

Furthermore, the delta-hedged option gain is related to the variance risk premium (VRP, defined as the difference between variance of the stock return under the physical measure and that under the risk neutral measure) (Proof in Appendix A.1):

$$E(\Pi_t) \approx \frac{1}{2}\frac{\partial^2 O}{\partial S^2} \times VRP \times S^2. \tag{14}$$

There are two implications that follow from Equation (14). First, as the option gamma is positive, a negative (positive) variance risk premium implies that $E(\Pi_t)$ will be negative (positive). A negative variance risk premium in the context is consistent with the notion that volatility rises with the negative jumps. Bollerslev and Todorov (2011) show that realized variance is priced due to its correlation with large negative jumps. The recent evidence in the variance swap market documented by Dew-Becker et al. (2015) further confirms the finding. The model framework in this paper is consistent with the recent findings. Second, as the option gamma is the largest for at-the-money options, the absolute value of $E(\Pi_t)$ is also the largest for the same underlying stock. However, after scaling the value of $E(\Pi_t)$ by the initial investment $O - \frac{\partial O}{\partial S} S_0$, the absolute return may not be the highest for at-the-money options. This may help to explain the empirical results in Section 4.

Proposition 2 states that even after controlling the impact of the underlying stock movement by dynamic delta-hedging, the expected scaled option return is still related to the structural characteristics of the underlying firm. From the derivation in Appendix A.2, we know that the scaled return is linked to the firm's characteristics through the variance risk premium. For firms with the same asset processes, the variance risk premium is determined by the sensitivity of the equity value with respect to the asset value, $\beta = \frac{\partial S}{\partial V} \frac{V}{S}$. In the model, the equity beta β is expressed as:

$$\beta = 1 + \frac{(1-\kappa)c}{rS} - \frac{(\gamma_1 + 1)S^{D_1}}{S} - \frac{(\gamma_2 + 1)S^{D_2}}{S},$$

Here, following Gomes and Schmid (2010), we use $S^{D_1} = aV^{-\gamma_1}$ and $S^{D_2} = bV^{-\gamma_2}$ to denote the value of the default option. The second term comes from the discontinuous jump term of the asset process. These two terms capture the effect of leverage on returns. If the bankruptcy trigger is exogenously determined by the strict-worth covenant, a is less than zero and decreases in the coupon value c. In this case, the equity risk is apparently increasing in the leverage ratio. Furthermore, the default option increases the equity risk. If the bankruptcy risk is endogenously determined by the equity holders, it is possible that a is larger than zero and increases in the coupon value. The default option lowers down the equity risk because the trigger is given by maximizing the equity value. However, the effect is not large enough to compensate the effect on risk of levering up equity cash flow. Overall, the risk of equity is increasing in firm's leverage ratio.

In reality, the relation between financial leverage and equity risk is more complex than the linear form. Gomes and Schmid (2010) show that, in a world where both corporate investment and financing decisions are endogenous, the relation between financial leverage and equity risk also depends on investment opportunities available to the firm. In other words, the mature firms tend to have higher leverage, but with fewer growth options. A heuristic representation of this relation in the context of my model is that,

$$\beta = 1 + \frac{(1-\kappa)c}{rS} - \frac{(\gamma_1 + 1)S^{D_1}}{S} - \frac{(\gamma_2 + 1)S^{D_2}}{S} + \frac{(\gamma_0 + 1)S^{G}}{S},$$

where S^G represents the value of the growth option. Depends on the relative effects of growth opportunity and leverage effect, mature firms may be less risky than the young firm. As equity risk is linked to the expected gain of delta-hedged options, it is important to control for growth option when examining the relation between leverage and expected delta-hedged option return. In the empirical analysis, we find a reverse relation between leverage ratio and the delta-hedged option return without controlling for firm characteristics. However, the relation is consistent with the theoretical prediction after controlling the growth opportunity such as firm size. Furthermore, the absolute value of delta-hedged option return is increasing in the firm size, suggesting that the investment-based asset pricing literature also sheds light on the pricing of equity options.

2.5 Simulations and implications of the model

In this subsection, we show the numerical results of this model and examine the relation between the structural characteristic of the firm and the delta-hedged option returns. The details of the simulation procedure are illustrated in Appendix A.3. Table 1 Panel A presents the parameter sets used in the simulations.

Panel A shows the value of the common parameters. We use asset volatility $\sigma = 0.25$, the median asset volatility of the US firms reported in Choi and Richardson (2015) and Correia et al. (2014). a is the risk aversion coefficient in the representative investor's utility function (power function). The value of a is obtained from Bliss and Panigirtzoglou (2004), who estimate the risk aversion coefficient of the power function from S&P 500 index options. The risk-free rate is assumed to be 4%, and the initial asset value is assumed to be 100. Panel B and C shows the value of parameters in the jump component of the firm's asset process. p_u is the probability that the asset return has a positive jump, p_d is the probability that the asset return has a negative jump, $1/\eta_u$ is the absolute mean of the upward jump size, and $1/\eta_d$ is the absolute mean of the downward jump size.

From Equation 13, we know that the sign of delta-hedged option gain depends on the relative size of the positive and negative jumps. In Figure 2a, we assume that the stocks have negative jumps on average ($p_u = 0.4, \eta_u = 8, \eta_d = 4$). In Figure 2b, we assume that the stocks have more positive jumps on average ($p_u = 0.4, \eta_u = 8, \eta_d = 4$). The horizontal axis shows levels of book leverage ratio c/rV. we compute the delta-hedged gains after one month scaled by the square of the initial stock price, for different book leverage ratio and for different jump intensities ($\lambda = 0, 0.5, 1$). The vertical axis shows the delta-hedged gains scaled by the square of the initial stock price. In Figure 3, we show the delta-hedged gains scaled by the initial investment. As these two figures show similar patterns, we scaled the delta-hedged gains scaled by the initial investment in the empirical analysis to understand better about the portfolio return.

Figure 2 and 3 show the nonlinear relationship between leverage and scaled delta-hedged gain. The nonlinear relation is similar as the relation between leverage and stock return in Doshi et al. (2015). When the jump size is on average negative (Panel (a)), the scaled delta-hedged gain is negative and decreasing in leverage. In addition, the relationship between these two variables becomes highly convex at high levels of leverage. Hence, it is important to take this non-linearity into account when examining the effect of leverage on scaled delta-hedged option gain. Furthermore, when the average jump size is positive (Panel (b)), the scaled delta-hedged gain is on positive and increasing in leverage. In other words, the sign of the effect of leverage on levered return depends on the sign of average jump size. In the empirical part of this paper, we will consider these two patterns of non-linearity and show that they play crucial roles when we examine the determinants of delta-hedged option return.

Based on the propositions and simulations, we form three hypotheses below and test them in Section 4.

Hypothesis 1: After controlling for growth options of the firm, the delta-hedged equity option return is decreasing in financial leverage and asset volatility.

Hypothesis 2: After controlling for growth options, financial leverage and asset volatility, the delta-hedged equity option return is decreasing in the covenant proxy: short-term debt divided by total debt of the firm.

Hypothesis 3: Higher order polynomials of the financial leverage and asset volatility play significant role in determining delta-hedged option returns.

3 Data

3.1 Option data and delta-hedged option return

The data on equity options are from the OptionMetrics Ivy DB database. The dataset contains information on the entire U.S. equity option market except for the financial firms, from January 1996 to August 2014. The data fields include daily closing bid and ask quotes, trading volume, open interest, implied volatility and the option's greeks computed by OptionMetrics based on standard market conventions. The IVs and greeks are calculated using a binomial tree model using Cox et al. (1979). Continuously-compounded zero-coupon interest rates are also obtained from OptionMetrics as a proxy for the risk-free rate.

Several filters are applied to select the options. First, to mitigate the problem of early exercise feature of American options, we select short-maturity options with expiration from 25 days to 35 days. Only at-the-money and out-of-the-money options are included. In addition, the options are included only if the underlying stock does not pay dividends during the remaining life of the option. Second, prices that violate arbitrage bounds are eliminated. Third, all observations are eliminated if the following conditions apply: (i) the ask is lower than or equal to the bid, (ii) the bid is equal to zero, (iii) the spread is lower than the minimum tick size (equal to 0.05 for option trading below 3 and 0.10 in any other cases), (iv) there is no volume or open interest.

After the filtering procedure, we select options under four categories: at-the-money (ATM) call, out-of-the-money (OTM) call, ATM put and OTM put. For each month, we select one option for each firm under each category, with moneyness closest to a specified value and maturity closest to 30 days. The specified value is 1 for ATM call and put, 0.95

for OTM call, and 1.05 for OTM put.

The delta-hedged option portfolio is constructed by holding a long position in an option, hedged by a short position in the underlying stock, such that the exposure of the option to the movement of the underlying stock is removed as much as possible. The definition of delta-hedged option gain follows Bakshi and Kapadia (2003). Let $C_{t,t+\tau}$ represents the price of an European call option at time t maturing at $t+\tau$ with strike price K. Denote the corresponding option delta by $\Delta_{t,t+\tau}$, and $\Delta_{t,t+\tau} = \frac{\partial C_{t,t+\tau}}{\partial S_t}$. The delta-hedged gains $\Pi_{t,t+\tau}$ is the gain or loss on a delta-hedged option position, deducting the risk-free rate earned by the net investment. In continuous time, delta-hedged call option gain is,

$$\Pi_{t,t+\tau} = C_{t+\tau} - C_t - \int_t^{t+\tau} \Delta_u dS_u - \int_t^{t+\tau} r_u(C_u - \Delta_u S_u)du.$$

where r_u is the annualized risk-free rate at time u. Consider a portfolio of a call option that is hedged discretely N times over the period $[t, t+\tau]$, where the hedged is rebalanced at each dates t_n, $n = 0, 1, ...N-1$. The discrete delta-hedged call option gain up to the maturity date $t+\tau$:

$$\begin{aligned} \Pi_{t,t+\tau} &= \max(S_{t+\tau} - K, 0) - C_t \\ &- \sum_{n=0}^{N-1} \Delta_{t_n}[S_{t_{n+1}} - S_{t_n}] - \sum_{n=0}^{N-1} r_n(C_t - \Delta_{t_n} S_{t_n})\frac{\tau}{N}. \end{aligned} \tag{15}$$

The definition for delta-hedged put option gains is similar as in Equation (15), except that the option price and delta are for the put options and the payoff of the put options is $\max(K - S_{t+\tau}, 0)$. To make the delta-hedged gains comparable across stocks, we scale the delta-hedged call option gain $\Pi_{t,t+\tau}$ by $\Delta_t S_t - C_t$ and by $P_t - \Delta_t S_t$ for the put options. In section 4, we refer to the scaled delta-hedged option gain $\Pi_{t,t+\tau}/(\Delta_t S_t - C_t)$ as the delta-hedged call option return.

From Proposition 2, we know that one determinant of the delta-hedged option return is the volatility of the jump component in the asset process. However, it is difficult to disentangle the volatility of jump component and diffusion component of the asset process using empirical data. Hence, we use asset volatility as a proxy. Following Correia et al.

(2014), we define the asset volatility as implied volatility of the equity option × (1-leverage ratio).

Christoffersen et al. (2014) document the illiquidity premia in the equity option market. To control the effect of liquidity, we define the option illiquidity measure as the relative bid-ask spread:

$$IL^o = \frac{2(O_{bid} - O_{ask})}{O_{bid} + O_{ask}}$$

where O_{bid} is the highest closing bid price and O_{ask} is the lowest closing ask price.

3.2 Stock and balance sheet data

Stock prices and the realized volatility are retrieved from the OptionMetrics database. The realized volatility is calculated over the past 30 calendar days, using a simple standard deviation calculation on the logarithm of the close-to-close daily total return. The idiosyncratic volatility is defined as the standard deviation of the error term of the Fama-French three-factor model estimated using the daily stock returns over the previous month. The definition follows Ang et al. (2006) and Cao and Han (2013).

The balance sheet data are obtained from Compustat database. Fama and French (1992) suggests that size is a potential risk factor, and it is reasonable to control size in the cross section of option returns. Firm size is defined as the natural logarithm of the firm's asset value on the balance sheet. The book leverage ratio is calculated as the sum of total debt (data item: LTQ) and the par value of the preferred stock (data item: PSTKQ), minus deferred taxes and investment tax credit (data item: TXDITCQ), divided by total asset (data item: ATQ). The financial firms are excluded for that their financing decisions cannot be explained by the conventional capital structure models.

Following Toft and Prucyk (1997), we use the maturity structure of the firm's debt as a proxy for the existence of net-worth hurdles, more specifically, the ratio of long-term debt due in one year plus notes payable to total debt. Leland (1994) argues that short-term debt can be associated with an exogenous bankruptcy trigger that equals the market value of debt. Long-term debt results in an endogenous bankruptcy point which is below its exogenous counterpart. Intuitively, this indicates that firms with a large proportion of debt due in the immediate future must pass a net-worth hurdle. Otherwise, they are unable to roll over their debt. Firms primarily financed by long-term debt need not overcome such a strict net-worth hurdle.

3.3 Summary statistics

After calculating the delta-hedged option returns, we merge the equity options data with their underlying stock information and the balance sheet data. The final data sample have $221,743$ observations for ATM calls, $201,474$ for OTM calls, $183,893$ for ATM puts and $170,716$ for OTM puts. Table 2 shows that the means of the delta-hedged options for call and put options are both -1.97% with a standard deviation 0.09. The average moneyness of the chosen options is 0.98 with a standard deviation of 0.03. The days to maturity ranges from 26 to 33 days across different months, with an average of 31 days. The detailed information for the delta-hedged option returns under the four categories are presented in Table 3.

4 Cross sectional analysis of delta-hedged option return

This section presents results of Fama-French regression results, tests several potential explanation of the results and reports some robustness checks.

4.1 Average delta-hedged option return

Table 3 presents time series average of delta-hedged option returns for individual stocks. It shows that the average delta-hedged return for ATM (OTM) call option is -1.72% (-2.25%) and -1.76% (-2.20%) for ATM (OTM) put options. Table 3 also reports the results of t-test for the time series mean of firms' delta-hedged option returns. There are 5809 firms in the ATM call option category. About 92% of them have negative average delta-hedged returns and 13% of them have significantly negative delta-hedged returns. In contrast, only 5 out of the 5809 firms have significantly positive delta-hedged returns. Results for the other three categories shows similar patterns.

4.2 Delta-hedged option returns, size and leverage

We study the relation between book leverage and delta-hedged option returns using monthly Fama-Macbeth regressions. For Table 4 to 6, the dependent variable for month t is the scaled return of delta-hedged ATM call option held until maturity, where the maturity of the options is about one month. All independent variables in the regression are predetermined at time t. The key variable of interest is the book leverage of the underlying firm. Table 6 provides robustness checks and results for the put options.

The univariate regression of delta-hedged option return on book leverage in Model 1 of Table 4 shows that the relation between the two is positive. However, when the firm size measured by asset value (Model 2) or by capitalization (Model 3) or implied volatility of the underlying stock (Model 4) are controlled in the regression, the relation becomes significantly negative. It confirms the theoretical finding that, the negative relation exists only in similar firms in all respects except that their book leverages are different. For firms with similar sizes, firms with higher leverage have lower delta-hedged returns. Compared to large firms, smaller firms usually have lower leverage ratio and higher asset volatility, which may lead to lower delta-hedged returns. This is one possible explanation why univariate regression shows positive relation between the leverage ratio and the delta-hedged option returns.

The significant negative relation between delta-hedged option returns and the leverage ratio is robust to different control variables. Note that when controlling for the asset volatility instead of implied volatility, the average estimated coefficient of book leverage (-0.041 in Model 5 and -0.042 in Model 6) and the corresponding t statistics are larger than that in other regressions. Following Correia et al. (2014), the asset volatility is calculated as $IV \times (1-BL)$. The result that controlling for asset volatility is the most efficient to establish the relation between the delta-hedged option return and book leverage also supports the theoretical model.

4.3 Controlling for volatility misestimation, idiosyncratic volatility and option illiquidity

In the recent literature, several variables have been found to be important determinants of delta-hedged option returns. Goyal and Saretto (2009) link the delta-hedged option returns to the difference between historical realized volatility and at-the-money implied volatility. They are motivated by the volatility misestimation and option mispricing. Cao and Han (2013) find negative relation between the delta-hedged option returns to idiosyncratic volatility, consistent with market imperfections and constrained financial intermediaries. In a recent research, (Christoffersen et al., 2014) report that an increase in option illiquidity decreases the current option price and predicts higher expected delta-hedged option returns. In Table 5, we control for the idiosyncratic volatility, option illiquidity and volatility deviation to examine whether they can explain the negative relation between delta-hedged option returns and book leverage. we find that the relation is robust after including different variables.

In Table 5, idiosyncratic volatility (IVol) is calculated as the standard deviation of the residuals of Fama-French three factor model estimated using the daily return over the previous month. Systematic volatility (SysVol) is the square root of (Vol^2-$IVol^2$), where Vol is the standard deviation of the stock return in the past month. Consistent with Cao and Han (2013), we find a negative relation between delta-hedged option returns and idiosyncratic volatility in Model 1 of Table 5. When both idiosyncratic volatility and systematic volatility are included in the regression in Model 1, the idiosyncratic volatility plays a determinant role, with estimated coefficient -0.025 and t statistics -10.34. In Model 2 of Table 5, after controlling for the idiosyncratic volatility and systematic volatility, the estimated coefficient of book leverage is negative and significant. It shows that the negative relation between book leverage and delta-hedged option return cannot be explained by the limits to arbitrage or market imperfections.

In Model 3 of Table 5, following Goyal and Saretto (2009), we measure the volatility deviation as the log difference of historical volatility (Vol) and implied volatility (IV). This variable has a significantly positive coefficient, which is consistent with Goyal and Saretto (2009). More importantly, after controlling for this proxy of volatility-related option mispricing, the coefficient for book leverage remains statistically significant. Thus, volatility-related mispricing does not explain the result.

Model 4 of Table 5 further controls for option illiquidity, measured as the difference between bid and ask option price divided by the average of bid and ask price. The result shows that on average, the coefficient of option illiquidity is significant and positive, consistent with the illiquidity premia in the equity option market by Christoffersen et al. (2014). In the presence of option illiquidity, the coefficient of book leverage is still negative and significant in Model 4. Moreover, including the asset volatility (IV_a) in Model 5 makes the magnitude of the estimated coefficient and t statistics of book leverage larger, and that of idiosyncratic volatility smaller. In addition, we control for the stock return during the life of the options in Model 4 and Model 5. The coefficients of the stock return are not significant in both regressions, suggesting that the implemented delta-hedging strategy is efficient and makes the portfolio not sensitive to the underlying stock price movement.

4.4 Delta-hedged return and the covenant effect

The model of this paper predicts that the delta-hedged option return of a firm with protected debt is more negative than that of a firm with unprotected debt. As suggested by (Toft and Prucyk, 1997), the maturity structure of the firm's debt can be used as a proxy for the existence of net-worth hurdles. Leland (1994) argues that short-term debt can be associated with an exogenous bankruptcy trigger V_b that equals the market value of debt on the issue date. Long-term debt, on the other hand, results in an endogenous bankruptcy point which is significantly below this value. Intuitively, this indicates that firms with a large proportion of debt due in the immediate future must pass a net-worth hurdle. Otherwise they are unable to roll over their debt. We, therefore, use the ratio of long-term debt due in one year to total debt as the first covenant proxy, CVNT1. The ratio of long-term debt due within five years to total debt is the second covenant proxy, CVNT5.

Table 6 reports the results of regressing the delta-hedged option return on the book leverage (BL) and the covenant proxies (CVNT1 and CVNT5). The regressions are estimated for four samples of delta-hedged option returns: at-the-money (ATM) call, out-of-the-money (OTM) call, at-the-money (ATM) put and out-of-the-money put. First, we find that, in the four samples, the estimated coefficient of the covenant proxies are significantly less than zero after controlling for book leverage (BL), the firm size, implied volatility and option illiquidity. The estimated coefficients range from -0.004 to -0.013 and the t statistics range from -1.61 to -4.26.

Second, short-term covenant proxy (CVNT1) has a larger effect on the delta-hedged option returns than the longer-term covenant proxy (CVNT5). This pattern shows in all four samples, for instance, the estimated coefficient of cvnt1 (-0.010) is twice as large as that of cvnt5 (-0.005) in the ATM call options category. This can be explained that long term debt due in the nearer future places a more strict net-worth covenant than that due in the further future. Thus, for firms with a similar leverage ratio and other characteristics, the effect of cvnt1 on delta-hedged option returns is larger than that of cvnt5. In addition, the magnitude of covenant proxy effect is larger for out-of-the-money options than at-the-money options. This is true for both call and put options. (EXPLANATION) Overall, the results present in Table 6 support the hypothesis predicted in the theoretical model.

4.5 The nonlinear effect of book leverage and asset volatility

Consider the mechanics of the model captured by Figure 2, which raises two important issues. First, the relation between the determinants (leverage and asset volatility) and returns is likely to be highly nonlinear. Any return regression that includes leverage as a regressor will therefore need to specify higher-order polynomials of leverage. A second problem is that the role of leverage differs on whether the delta-hedged option return is positive or negative. This is evident from Figure 2. If the firm's delta-hedged option return (variance risk premium) is positive, leverage will increase the return, and the first-order leverage term will be estimated with a positive coefficient, but if the delta-hedged option return is negative, higher leverage will show up with a negative coefficient. If we ignore this and regress the resulting sample of negative and positive levered returns on leverage, the resulting estimates may not be informative regarding the role of leverage.

We explore these issues in Table 7, in which we regress the delta-hedged returns on leverage, asset volatility, interaction terms and higher order terms of these two determinants. The two determinants are interacted with a dummy variable $1_{ret>0}$ ($1_{ret<0}$), which is equal to one when the equity return is positive (negative). In Model 1, the coefficient of the interaction term $BL \times 1_{ret>0}$ ($BL \times 1_{ret<0}$) is significantly positive (negative). After including the interaction term of asset volatility with dummies in Model 2, the coefficients of all interaction terms are consistent with the theory, as expected. In Model 3 and 4, we include higher order interaction terms, which are all significant. The adjusted R^2 also increases drastically from about 10% in Table 5 to more than 40% in Model 4 Table 7. Interestingly, the size effect remains statistically significant. The idiosyncratic volatility effect remains, but the magnitude decreases. The effect of option illiquidity does not exist after including the structural variables, leverage and asset volatility.

5 Leverage-based trading strategy

We now investigate the cross-sectional relation between delta-hedged option returns using portfolio sorting approach. This section confirms the Fama-Macbeth regression results in the previous section, propose a leverage-based trading strategy and examine the impact of trading cost on the profitability of the trading strategy.

As in Section 4, for each optionable stock, we choose an option with a time-to-maturity closest to 30 days for each of the four option categories: ATM call, OTM call, ATM put and OTM put. At the end of each month, we first sort stocks with traded options into five quintiles based on their sizes, (or asset volatility) and then, within each size quintile, we further sort the stocks by their book leverage ratio into five quintiles. In each size quintile, the trading strategy buys the delta-hedged options on stocks ranked in the bottom leverage quintile and sells the delta-hedged options on stocks ranked in the top leverage quintile. The delta-hedged options are rebalanced every day based on their delta and held until maturity. The delta-hedged option returns are calculated in the same way as in Section 4.

5.1 Double sorts on size and leverage

Table 8 reports the equal-weighted average return of 25 portfolios for delta-hedge call and put options. Each portfolio consists of selling delta-hedged options on stocks located in a given quintile sorted by size and leverage. Different from the summary statistics in Table 2 and Table 3, the returns are positive on average in Table 8, because the short positions of the delta-hedged options are considered in the trading strategy. Table 8 also reports in the "5-1" column the difference in the average return of the top and bottom book leverage quintile in each size quintile. The t-statistics for the time series of "5-1" portfolios are computed using a Newey-West correction for serial correlation using 2 lags for monthly returns.

Panel A of Table 8 reports the results for monthly delta-hedged returns on ATM call options. Panel A shows that the 5-1 portfolios which sell the delta-hedged calls with the highest leverage ratio and buy the ones with the lowest leverage ratio earn a significant positive return from size quintile 1 to size quintile 4. From Panel B to Panel D, all the 5-1 portfolios earn positive returns on average, with most of them statistically significant. In general, the effect of book leverage on the delta-hedged option return is decreasing with the firms' asset sizes. As firms grow larger, they have better opportunities to issue more debt. In that case, leverage ratio becomes a less important indicator for bankruptcy. If the bankruptcy risk premium is considered as a dominant component in the delta-hedged option return, the effect of book leverage is smaller in larger firms. Moreover, the effect of book leverage on OTM delta-hedged options is stronger than that on ATM delta-hedged options. For example, in the first size quintile, the average 5-1 portfolio return of delta-hedged ATM call options is 0.44 with t statistics 2.78, while for OTM call options, the return is 0.88 with t statistics 4.81.

Interestingly, Vedolin (2012) find relatively weak evidence for the relation between financial leverage and variance risk premium. One explanation is that the firm characteristics are not controlled in the analysis. The implication of the theoretical model in this paper is that for two otherwise same firms, higher leverage contributes to lower delta-hedged option returns. Hence, controlling for the firm characteristics is essential for disentangling the relation between leverage and delta-hedged option return.

5.2 Double sorts on asset volatility and leverage

In the previous section, we use Fama-Macbeth regressions to show that the negative relation between delta-hedged option return and leverage ratio is more evident after controlling for firms' asset volatility. Table 9 uses the conditional double sort to confirm the finding. At the end of each month, we first sort the stocks into five quintiles by their asset volatility, calculated as $IV \times (1 - BL)$, where IV is the implied volatility and BL is the book leverage. Within each asset volatility quintile, the stocks are further sorted into five quintiles by their book leverage. The equal weighted average returns of selling the delta-hedged options on the stocks in each quintile are reported in Table 9.

Table 9 shows that, in all 4 Panels of different option categories and all asset volatility quintiles, selling delta-hedged options on high leverage stocks significantly outperforms selling delta-hedged options on low leverage stocks. The average outperformance ranges from 0.85% to 1.96%. Consistent with the theory, investors selling delta-hedged options with higher asset volatility get higher returns than that with lower asset volatility. For instance, the delta-hedged returns in the fifth asset volatility quintile are always larger than that in the first asset volatility quintile in Panel A to Panel D. In addition, the effect of book leverage on delta-hedged options is larger for OTM options than ATM options and larger for put options than for call options.

6 Conclusion

How does the Merton-type structural model explain the cross-sectional variation of equity option return? This paper argues in a jump-diffusion capital structure model that, firm's leverage ratio and asset volatility are two determinants of the expected return of delta-hedged equity options. We first derive the expected return of the delta-hedged equity option based on a capital structure model, in which the asset value of a firm is driven by a double exponential jump-diffusion process. In the model, the expected return of the delta-hedged equity option is closely linked to option gamma and the variance risk premium of the underlying firm, which is related to firm's financial characteristics. Furthermore, the theory suggests that the relation between the determinants and the delta-hedged equity option returns is nonlinear. Empirically we find that these two structural variables can explain a large portion of the cross-sectional variation in the data and even subsume information in other determinants documented in the literature, such as idiosyncratic volatility and liquidity. The results of double sorting exercise are consistent with the theory. There is also evidence of the nonlinear relation between the determinants and the delta-hedged equity option returns: the determinants affect positive and negative returns differently. These findings are robust across calls, puts, and different moneyness levels.

Overall, this paper explores one channel, i.e. financial decision of the firm, that differentiates the pricing of variance risk premium of individual stocks. The model indicates that the first-order equity risk can transfer directly to higher-order risks such as the variance risk and jump risk. There are at least two dimensions of research that can be explored in the future. The first dimension is to consider the investment channel and the leverage channel simultaneously. The interaction of the two channels is able to explain more empirical patterns in the equity option market. The second dimension for further research is to extend the model and accommodate more complex capital structures, e.g. security provisions and conversion rights. The extended model can examine how the heterogeneity of firm's debt structure affects firms' default incentives and the expected return of delta-hedged equity options. These questions are left for future research.

A Appendix

A.1 Proof of Proposition 1

The first part in Equation (12) can be expanded using the Taylor expansion:

$$E^Q[O(S) - O(S_-)] \approx E^Q[\frac{\partial O}{\partial S}(S - S_-) + \frac{1}{2}\frac{\partial^2 O}{\partial S^2}(S - S_-)^2]. \tag{16}$$

Similarly, under the physical measure, we approximate the expected change of the option price until the second order:

$$E[O(S) - O(S_-)] \approx E[\frac{\partial O}{\partial S}(S - S_-) + \frac{1}{2}\frac{\partial^2 O}{\partial S^2}(S - S_-)^2]. \tag{17}$$

Substituting Equation (16) and (17) into Equation (12), we get Equation (13) in Proposition 1. Using Taylor expansion, the change of stock price in jump times can be further expanded. The quadratic term in Equation (1) is approximately equal to,

$$(S(V) - S(V_-))^2 \approx (\frac{\partial S}{\partial V}(V - V_-) + \frac{1}{2}\frac{\partial^2 S}{\partial V^2}(V - V_-)^2)^2 \tag{18}$$

There is quadratic, cubic and quatic terms in the above formula. Since higher order terms play a less important role, we only consider the first order term such that Equation (13) is simplified as,

$$E(\Pi_t) \approx \int_0^t \frac{1}{2}\frac{\partial^2 O_u}{\partial S_u^2}(\frac{\partial S_u}{\partial V_u})^2(\lambda E[V_u - V_{u-}]^2 - \lambda^Q E^Q[V_u - V_{u-}]^2)du.$$

Note that the option price is a strictly convex function of the underlying asset price and option gamma $\frac{\partial^2 O}{\partial S^2}$ is positive for both call and put options. $\frac{\partial S}{\partial V}$ is also positive because stock price S is a call option on the firm's asset V. Recall the expressions of the jump intensity of the asset value under physical and risk neutral measure λ and λ^Q, and density of the jump size under the physical and risk neutral measure in Section 2.1 and substitute them in

Equation (13),

$$\lambda E[V - V_{-}]^2 - \lambda^Q E^Q[V - V_{-}]^2 \tag{19}$$

$$= \lambda(\xi^{(2)} + \xi^{(0)} - 2\xi^{(1)} - (\xi^{(\alpha+1)}) + \xi^{(\alpha-1)} - 2\xi^{(\alpha)}))V_{-}^2. \tag{20}$$

where $\xi^{(x)}$ is a function of x given in Equation (4) and α ($0 < \alpha < 1$) is the risk aversion coefficient in the utility function. Let $f(x) = \xi^{(x)}$. To show that (19) is less than zero, we have to prove $f'(\alpha+1) + f'(\alpha-1) - 2f'(\alpha) < 0$. In other words, $f'(x)$ is a concave function for $0 < x < 1$. To prove this, we calculate the third derivative of $f(x) = \xi^{(x)}$:

$$\frac{\partial^3 f(x)}{\partial x^3} = \frac{6\eta_u^4\eta_d^4\ (p_u/\eta_u^3 - p_d/\eta_d^3)}{(\eta_u - \alpha)^4(\eta_d + \alpha)^4}$$

If the parameters in the above equation satisfies the following two conditions, then $f'(x)$ is a concave function of x. The first condition is that the absolute value of the negative jump size is larger than the positive jump size on average, that is, $1/\eta_d > 1/\eta_u$. The second condition is that the expected jump size is less than zero: $E[y] = \frac{p_u}{\eta_u} - \frac{p_d}{\eta_d} < 0$. When the parameters of the underlying asset process follows the above two conditions, the expected delta-hedged option return is negative.

Next, we derive the relation between $E(\Pi_t)$ and the variance risk premium over the time period 0 to t. The variance of $\log(S_t)$ is measured by its quadratic variation (QV). For a period from time 0 to t, it is given by,

$$[\log(S), \log(S)]_{(0,t]} = \int_0^t (\frac{\partial S_s}{\partial V_s}\frac{V_s}{S_s}\sigma)^2 ds + \sum_{0<s\leq t}(\frac{S_s - S_{s-}}{S_s})^2.$$

The randomness in QV generates variance risk. As the randomness in this model comes from the jumps in the stock price, only the jump part contributes to the variance risk premium. The variance risk premium (VRP) of the stock is defined as the wedge between the expected quadratic variation under the physical measure and the risk neutral measure. Thus, the VRP over the time period $(0, t]$ is,

$$\begin{aligned} VRP &= E^P[[\log(S), \log(S)]_{(0,t]}] - E^Q[[\log(S), \log(S)]_{(0,t]}] \\ &\approx \int_0^t (\frac{1}{S})^2 (\frac{\partial S}{\partial V})^2 (\lambda E[V - V_-]^2 - \lambda^Q E^Q[V - V_-]^2) dt. \end{aligned}$$

The second step uses the Taylor expansion in Equation (18). If we ignore the movement in the stock price S, the variance risk premium is related to the delta-hedged option return by:

$$E(\Pi_t) = \int_0^t \frac{1}{2} \frac{\partial^2 O}{\partial S^2} \frac{dVRP}{dt} S^2 ds.$$

A.2 Proof of Proposition 2

If we ignore the movements in the stock price and the option gamma from time 0 to t, then the relation between VRP and the expected delta-hedged gain can be rewritten as,

$$E(\Pi_t)/S_0^2 \approx \frac{1}{2} \frac{\partial^2 O}{\partial S^2} \times VRP.$$

The scaled delta-hedged gain $E(\Pi_t)/S_0^2$ is related to the capital structure of the firm through the variance risk premium, especially from the term: $(\frac{1}{S}\frac{\partial S}{\partial V})^2$. We will prove that this term is increasing in the coupon value (c) of the firm. If the book leverage ratio of the firm is approximated as $\frac{c}{rV}$, then the absolute value of the scaled $E(\Pi_t)$ is increasing in the book leverage, for the same level of asset value.

The partial derivative of the equity value S with respect to the asset value V is:

$$\frac{\partial S}{\partial V}(V; V_B) = 1 - a\gamma_1 V^{-\gamma_1 - 1} - b\gamma_2 V^{-\gamma_2 - 1}, \;\; \gamma_1 > 0, \;\; \gamma_2 > 0,$$

in which $a = \frac{(1-\kappa)cd_1}{r} V_B^{\gamma_1} - c_1 V_B^{\gamma_1+1}$ and $b = \frac{(1-\kappa)cd_2}{r} V_B^{\gamma_2} - c_2 V_B^{\gamma_2+1}$. The parameters c_1, d_1, c_2, d_2, γ_1 and γ_2 given in Section 2.2 are only related to the parameters in the asset process, not to the capital structure of the firm. As $\frac{1}{S}$ is increasing in c, $\frac{1}{S}\frac{\partial S}{\partial V}$ will be definitely increasing in c, if $\frac{\partial S}{\partial V}$ is increasing in c,

$$\frac{\partial S/\partial V}{\partial c} = -\gamma_1 V^{-\gamma_1 - 1}\frac{\partial a}{\partial c} - \gamma_2 V^{-\gamma_2 - 1}\frac{\partial b}{\partial c}, \tag{21}$$

The sign of the above expression depends on several factors. Two situations, whether the firm faces an exogenous or endogenous trigger, are considered. In the first case, firm's debt is protected by a strict net-worth covenant. This covenant triggers bankruptcy when the asset value V hits the threshold $V_B = \frac{c}{r\alpha}$. In the second case, the bankruptcy trigger is determined endogenously by the debt holders. As showed in Equation (9),

$$V_B^* = \frac{\epsilon c}{r}, \text{ where } \epsilon = \frac{(1-\kappa)(d_1\gamma_1 + d_2\gamma_2)}{c_1\gamma_1 + c_2\gamma_2 + 1}. \tag{22}$$

In both situations, $V_B = xc$ where x is a constant. Substituting into the expression of a, we have,

$$\frac{\partial a}{\partial c} = (\frac{(1-\kappa)d_1}{r} - c_1 x)x^{\gamma_1}c^{\gamma_1+1}.$$

Note that Equation (21) mainly depends on the sign of the first term, because the second term plays a less important role here ($0 < \gamma_1 < \eta_d < \gamma_2$). As $V_B > V_B^*$ and $x > x^*$, it follows that,

$$\frac{\partial S}{\partial V}(V;V_B) > \frac{\partial S}{\partial V}(V;V_B^*),$$
$$\frac{\partial S/\partial V}{\partial c}(V;V_B) > \frac{\partial S/\partial V}{\partial c}(V;V_B^*).$$

Hence, the absolute scaled delta-hedged gain is higher for the firms with a strict net-worth covenant than for those without it; after increasing the leverage ratio, the change in the absolute scaled delta-hedged gain is also higher for the firms with strict net-worth covenant.

From the above derivation, we know that the term $\frac{1}{S}\frac{\partial S}{\partial V}$ for the firms with strict net-worth covenant is more likely to increase with the coupon value c than those without. It can be shown that even for firms with endogenous bankruptcy trigger, with reasonable parameter assumptions, the term $\frac{1}{S}\frac{\partial S}{\partial V}$ is increasing in c. The proof is available upon request.

A.3 Details of the simulation procedure

Based on the parameters in Table 1, we first simulate the diffusion and the jump component of the firm's asset process under the physical measure and the risk neutral measure for $10,000$ times. Note that the volatility of the diffusion term is constant, and volatility risk is not priced in this model. Hence, the diffusion terms are the same under the physical and the risk neutral measure.

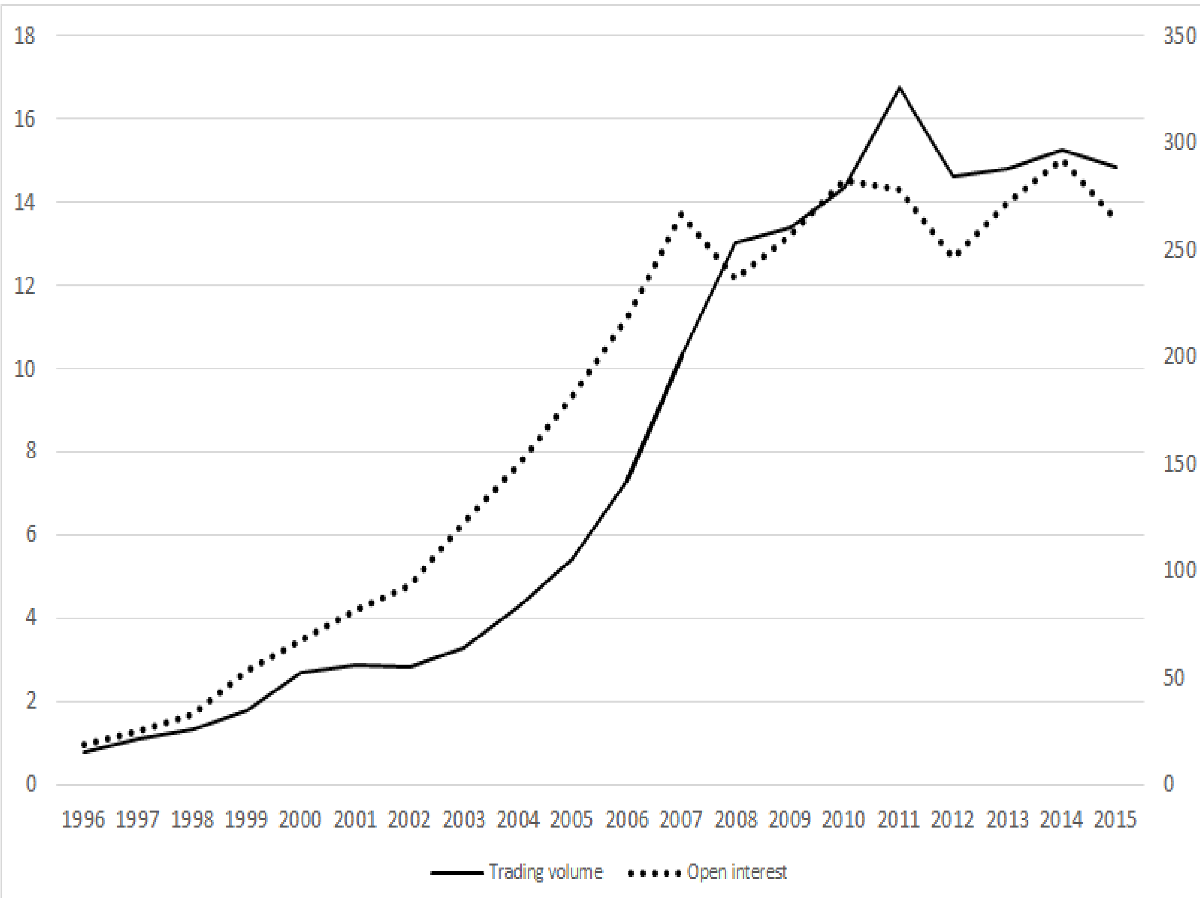
Second, starting from the initial asset value $V_0 = 100$, we simulate $10,000$ paths of daily returns. In each path, there are 21 daily returns, consisting of the daily returns in one month.

Third, for different level of leverage ratio, the equity value of the firm is then calculated based on Equation 8. The daily value are available both under the physical and under the risk neutral measure.

Fourth, the equity option values is the discounted average of the payoff of the option at the end of the month under the risk neutral measure. In this numerical example, we only consider at-the-money call option, i.e. the strike price of the option is equal to the initial stock price.

Finally, we construct a portfolio consisting of buying a call equity option and daily delta-hedging the underlying stock. The share of the stock is approximated as the delta, the first order derivative of the option price with respect to the stock price under the Black-Scholes model.

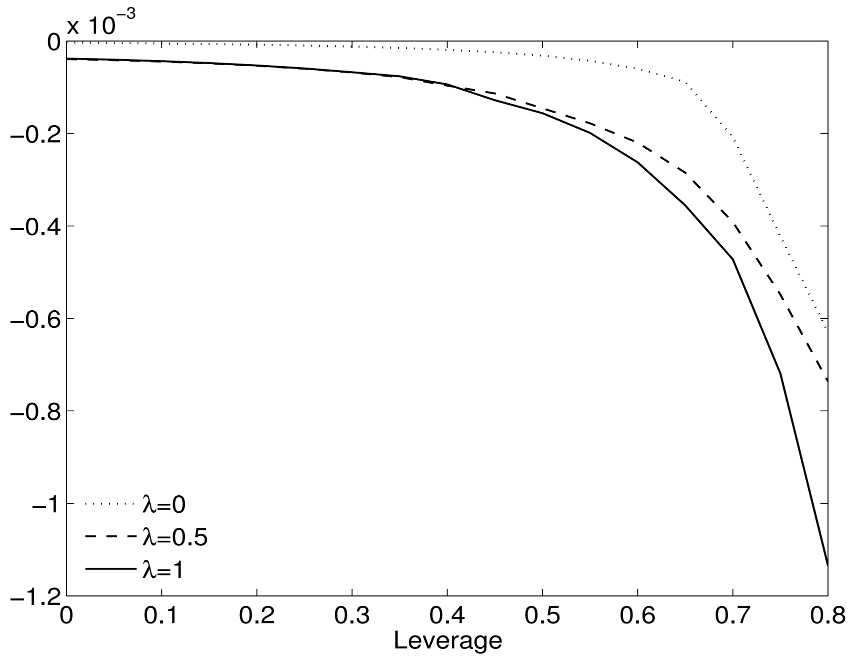
Figure 1: Trading volume and open interest of equity options over time (Million)



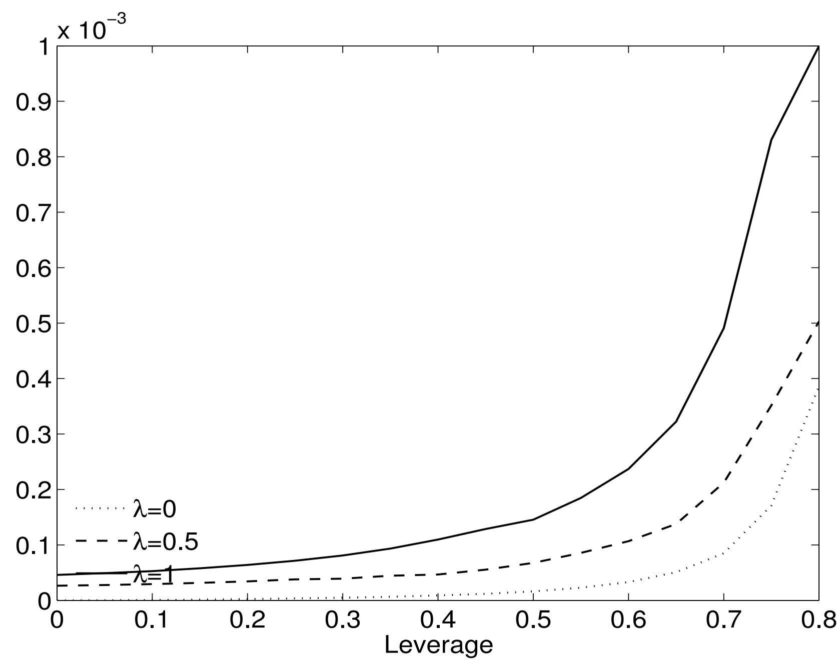
Note: This figure shows daily average trading volume (the black line) and open interest (the dashed line) of equity options in the US market from 1996 to 2015. The left axis is associated with trading volume and the right axis is associated with open interest. Data source: The Options Clearing Corporaion.

Figure 2: Leverage and scaled delta-hedged option gain
(Scaled by square of stock price)

(a) Negative jumps on average



(b) Positive jumps on average



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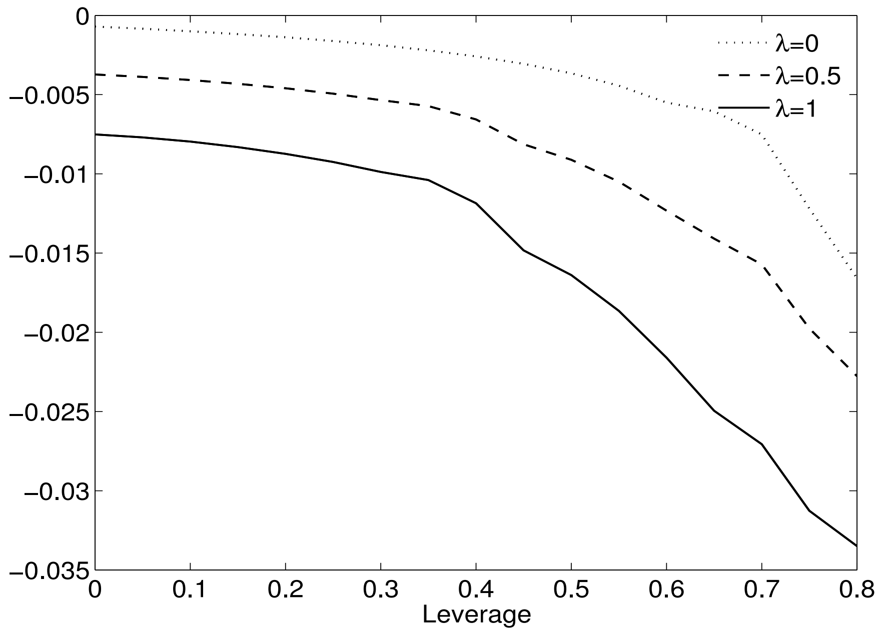
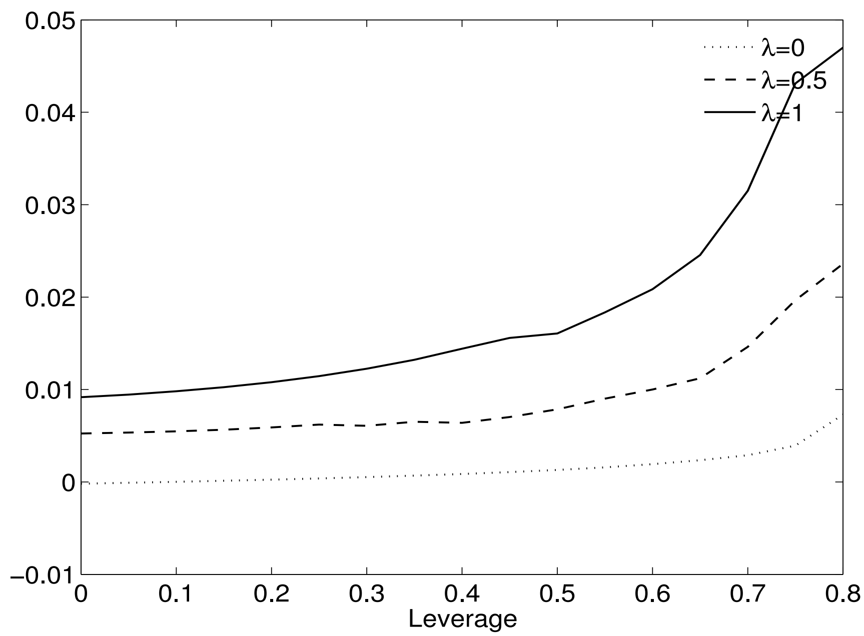
Note: This figure shows the relation between leverage and scaled delta-hedged gain generated by the model in Section 2.3, when the jump size is negative on average. The top panel presents scaled delta-hedged gain generated from the model for different leverage and jump intensity

Figure 3: Leverage and scaled delta-hedged option gain
(Scaled by the initial investment)

(a) Negative jumps on average

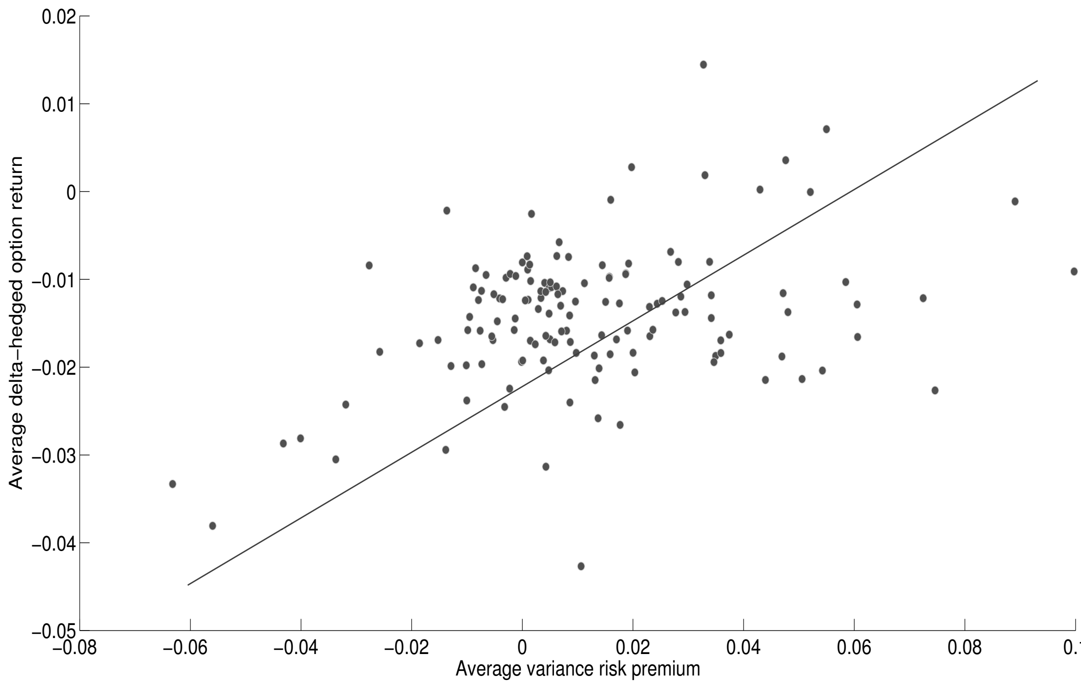


(b) Positive jumps on average



Note: This figure shows the relation between leverage and scaled delta-hedged gain generated by the model in Section 2.3, when the jump size is positive on average. The top panel presents scaled delta-hedged gain generated from the model for different leverage and jump intensity

Figure 4: Average variance risk premium and average delta-hedged option return



Note: This scatter plot shows the relation between average variance risk premium and average delta-hedged option return. The scatter presents the relation for firms with more than 150 (out of 224 months) observations of delta-hedged option return. The variance risk premium is calculated as the difference between realized volatility in the previous month and the implied volatility of the at-the-money call option at the beginning of the month.

Table 1: Parameter sets used in the simulations

Panel A: Common Parameters

Parameters	σ	κ	r	α	V_0	ρ	a	σ_1
Value	0.25	0.35	0.04	0.9	100	0.5	0.2	0.2

Panel B: Parameters in the jump component (More negative jumps)

Parameters	p_u	p_d	η_u	η_d	λ
Value	0.4	0.6	8	4	0/ 0.5/ 1

Panel C: Parameters in the jump component (More positive jumps)

Parameters	p_u	p_d	η_u	η_d	λ
Value	0.6	0.4	4	8	0/ 0.5/ 1

Note: This table presents parameters sets for simulating the delta-hedged option returns. Panel A shows value of the common parameters. σ is the asset volatility of the firm, κ is the tax rate, r is the risk free rate, α is the percentage of the asset value that the debt holders can get upon bankruptcy, V_0 is the initial asset value of the firm, ρ is the correlation between diffusion terms in the asset process and in the consumption process, a is the risk aversion coefficient in the representative investor's utility function (power function). σ_1 is the volatility of the consumption process. Panel B and C shows value of parameters in the jump component of the firm's asset process. p_u is the probability that the asset return has a positive jump, p_d is the probability that the asset return has a negative jump, $1/\eta_u$ is the absolute mean of the upward jump size, and $1/\eta_d$ is the absolute mean of the downward jump size.

Table 2: Summary statistics of option data

Variable	Mean	Std. Dev.	10th Pctl	25th Pctl	Median	75th Pctl	90th Pctl
Panel A: Call options							
Delta-hedged return until maturity(%)	-1.97	9.28	-9.31	-5.18	-2.03	0.52	4.40
Moneyness=S/K	0.98	0.03	0.94	0.96	0.98	1.00	1.01
Days to maturity	30.96	2.47	26	30	32	33	33
Relative bid-ask spread	0.21	0.20	0.05	0.09	0.15	0.26	0.43
Implied volatility (IV)	0.47	0.24	0.23	0.30	0.42	0.58	0.79
Delta	0.46	0.11	0.30	0.38	0.47	0.54	0.59
Panel B: Put options							
Delta-hedged return until maturity(%)	-1.97	7.91	-8.28	-4.70	-2.05	0.04	3.29
Moneyness=S/K	1.02	0.03	0.99	1.00	1.02	1.05	1.06
Days to maturity	30.89	2.49	26	30	32	33	33
Relative bid-ask spread	0.19	0.18	0.05	0.08	0.14	0.24	0.40
Implied volatility (IV)	0.49	0.25	0.24	0.31	0.43	0.60	0.81
Delta	-0.40	0.10	-0.53	-0.47	-0.40	-0.32	-0.26
Panel C: Other variables							
Book leverage (BL)	0.48	0.24	0.16	0.29	0.48	0.64	0.83
Size=log(asset value)	7.64	2.02	5.14	6.18	7.52	8.96	10.33
Long term debt due in one year	0.03	0.09	0.00	0.00	0.00	0.03	0.08
Long term debt due in five years	0.17	0.26	0.00	0.00	0.10	0.26	0.47
Realized volatility (RVol)	0.46	0.32	0.19	0.26	0.38	0.57	0.83
Idiosyncratic volatility (IVol)	0.38	0.28	0.14	0.20	0.31	0.48	0.71
VRP	-0.03	2.79	-0.20	-0.04	0.02	0.07	0.17

Note: This table reports the descriptive statistics of delta-hedged option returns for the pooled data. The data sample period is from January 1996 to August 2014. For call options, delta-hedged return until maturity is calculated as delta-hedged gain scaled by $(\Delta S - C)$, where Δ is the Black-Scholes option delta, S is the underlying stock price and C is the price of call option. For put options, it is scaled by $(P - \Delta S)$. Delta-hedged gain is the change in the value of a portfolio consisting of one long option position, daily hedged by the underlying stock, so that the portfolio is not sensitive to the stock price movement. Moneyness is the ratio of stock price over option strike price. Days to maturity is the calenda days until option expiration. Relative bid-ask spread is the difference between bid and ask option price divided by the avereage of bid and ask price. Implied volatility (IV), delta and vega are provided by OptionMetrics based on Black-Scholes model. Realized volatility is the standard deviation of the daily stock return during the past 30 days. Idiosyncratic volatility (IVol) is the standard deviation of the residuals of Fama-French three factor model estimated using the daily return over the previous month. Size is the logrithm of the firm's asset. Book leverage is the sum of total debt and the par value of the preferred stock, minus deferred taxes and investment tax credit, divided by total asset.

Table 3: Summary statistics of delta-hedged option returns

		Obs.	Mean	Std.Dev.	No. of firms	mean < 0	$t < -2$	mean > 0	$t > 2$
Call	ATM	221,743	-1.72	8.60	5809	5342	762	467	5
	OTM	201,474	-2.25	9.96	5793	5255	726	538	8
Put	ATM	183,893	-1.76	6.82	5807	5150	691	657	7
	OTM	170,716	-2.20	8.93	5676	4991	728	685	6

Note: This table reports summary statistics of delta-hedged returns for call and put options under the at-the-money (ATM) and out-of-the-money (OTM) categories. The third to sixth columns represent number of observations, mean, standard deviation, and number of firms. The column mean $< 0(> 0)$ reports the number of firms with mean of the delta-hedged returns less (more) than zero. The column $t < -2(> 2)$ reports the number of firms with t statistics of delta-hedged returns less (more) than two.

Table 4: Delta-hedged option returns and book leverage

	MODEL1	MODEL2	MODEL3	MODEL4	MODEL5	MODEL6
Intercept	-0.020	-0.037	-0.032	0.008	0.022	0.011
	(-9.77)	(-13.34)	(-12.86)	(-4.43)	(-9.17)	(-2.94)
BL	0.005	-0.008	-0.007	-0.005	-0.041	-0.042
	(-2.41)	(-3.64)	(-2.87)	(-2.41)	(-12.00)	(-12.49)
SIZE_A		0.003				0.001
		(-13.03)				(-5.33)
SIZE_S			0.003			
			(-14.54)			
IV				-0.049		
				(-13.82)		
IV_a					-0.078	-0.069
					(-14.05)	(-11.50)
Average adj. R^2	0.004	0.013	0.015	0.038	0.032	0.035

Note: This table reports the average coefficients (t statistics) from monthly cross-sectional Fama-MacBeth regressions of at-the-money delta-hedged call option returns. The sample period covers data from January 1996 through August 2014. BL (Book leverage) is the sum of total debt and the par value of the preferred stock, minus deferred taxes and investment tax credit, divided by total asset. Size_a is the logrithm of the firm's asset. Size_s is the logrithm of the firm's market capitalization. IV is the Black-Scholes option implied volatility. IV_a is the firm's asset volatility, which is calculated as IV*(1-BL). Reported are coefficients and Dama-MacBeth t-statistics with Newy-West correction for serial correlation.

Table 5: Controling for idiosyncratic volatility and option illiquidity

	MODEL1	MODEL2	MODEL3	MODEL4	MODEL5
Intercept	-0.009	-0.023	-0.008	-0.048	0.003
	(-7.62)	(-9.47)	(-2.33)	(-4.56)	(-0.3)
IVol	-0.025	-0.018	-0.033		-0.001
	(-10.34)	(-7.65)	(-10.13)		(-0.46)
SysVol	0.003	0.002	-0.008		
	(-1.03)	(-0.73)	(-1.76)		
Size_A		0.002	0.001	0.003	0.001
		(-7.55)	(-3.29)	(-13.26)	(-5.31)
BL		-0.006	-0.006	-0.009	-0.045
		(-3.26)	(-3.03)	(-4.87)	(-12.91)
Vol deviation			0.022		
			(7.09)		
Option Illiquidity				0.016	0.008
				(-3.01)	(-1.68)
Stock return				-0.005	-0.006
				(-0.53)	(-0.64)
IV_a					-0.073
					(-12.26)
Average adj. R^2	0.021	0.027	0.045	0.067	0.091

Note: This table reports the average coefficients (t statistics) from monthly cross-sectional Fama-MacBeth regressions of at-the-money delta-hedged call option returns. The sample period covers data from January 1996 through August 2014. Idiosyncratic volatility (IVol) is the standard deviation of the residuals of Fama-French three factor model estimated using the daily return over the previous month. Systematic volatility (SysVol) is the square root of (Vol^2-$IVol^2$), where Vol is the standard deviation of the stock return in the past month. Size_a is the logrithm of the firm's asset. Book leverage (BL) is the sum of total debt and the par value of the preferred stock, minus deferred taxes and investment tax credit, divided by total asset. Vol deviation is calculated as the log difference between VoL and IV. OptionIll is the difference between bid and ask option price divided by the avereage of bid and ask price. Stock return is the stock return of the underlying firm until maturity. IV_a is the firm's asset volatility, which is calculated as IV*(1-BL). Reported are coefficients and Dama-MacBeth t-statistics with Newy-West correction for serial correlation.

Table 6: Delta-hedged return and the covenant effect

	Call options				Put options			
	ATM		OTM		ATM		OTM	
Intercept	0.003	0.004	-0.001	0	0.008	0.008	0.011	0.012
	(-0.84)	(-0.95)	(-0.22)	(-0.09)	(-3.17)	(-3.26)	(-3.05)	(-3.17)
BL	-0.007	-0.006	-0.010	-0.009	-0.004	-0.004	-0.006	-0.005
	(-3.29)	(-2.99)	(-4.06)	(-3.79)	(-2.60)	(-2.32)	(-2.19)	(-2.01)
Size_A	0.001	0.001	0.001	0.001	0	0	0	0
	(-1.72)	(-1.58)	(-1.75)	(-1.64)	(-0.23)	(-0.15)	(-0.52)	(-0.64)
IV	-0.046	-0.046	-0.049	-0.050	-0.052	-0.052	-0.059	-0.059
	(-10.29)	(-10.40)	(-10.39)	(-10.49)	(-17.67)	(-17.94)	(-14.77)	(-15.35)
Option Illiquidity	0.002	0.002	0.005	0.006	0.002	0.003	0.002	0.002
	(-0.43)	(-0.48)	(-1.65)	(-1.81)	(-0.68)	(-0.82)	(-0.53)	(-0.64)
cvnt1	-0.010		-0.013		-0.007		-0.011	
	(-2.73)		(-2.74)		(-1.61)		(-1.68)	
cvnt5		-0.005		-0.006		-0.004		-0.005
.		(-4.26)		(-4.11)		(-3.30)		(-3.13)
Average adj. R^2	0.043	0.043	0.036	0.036	0.056	0.056	0.044	0.044

Note: This table reports the average coefficients (t statistics) from monthly cross-sectional Fama-MacBeth regressions of at-the-money delta-hedged call option returns. The sample period covers data from January 1996 through August 2014. Book leverage (BL) is the sum of total debt and the par value of the preferred stock, minus deferred taxes and investment tax credit, divided by total asset.Size_A is the logrithm of the firm's asset. Implied volatility (IV) is provided by OptionMetrics based on Black-Scholes model. Relative bid-ask spread is the difference between bid and ask option price divided by the avereage of bid and ask price. Stock return is the stock return of the underlying firm until maturity. CVNT1 is the ratio of long term debt due in one year, divided by total long term debt. CVNT5 is the ratio of long term debt due within five years, divided by total long term debt. Reported are coefficients and Dama-MacBeth t-statistics with Newy-West correction for serial correlation.

Table 7: The nonlinear effect of book leverage and asset volatility

	MODEL1	MODEL2	MODEL3	MODEL4
IV_a	-0.077		-0.07	
	(-13.85)		(-12.43)	
$BL \times 1_{ret>0}$	0.067	0.017	0.238	-0.034
	(19.21)	(6.57)	(20.96)	(-5.60)
$BL \times 1_{ret<0}$	-0.084	-0.058	-0.167	-0.044
	(-19.78)	(-18.06)	(-15.66)	(-7.15)
$IV\_a \times 1_{ret>0}$		0.098		0.128
		(12.79)		(14.76)
$IV\_a \times 1_{ret<0}$		-0.14		-0.136
		(-35.91)		(-35.30)
$BL^2 \times 1_{ret>0}$			-0.261	0.067
			(-18.42)	-8.8
$BL^2 \times 1_{ret<0}$			0.117	-0.018
			(11.98)	(-3.67)
SIZE_a			0.001	0.001
			(6.03)	(5.63)
Option Illiquidity			-0.003	-0.001
			(-0.76)	(-0.19)
IVol				-0.006
				(-4.44)
Average adj. R^2	0.256	0.402	0.315	0.409

Note: This table reports the average coefficients (t statistics) from monthly cross-sectional Fama-MacBeth regressions of at-the-money delta-hedged call option returns. The sample period covers data from January 1996 to August 2014. IV_a is the firm's asset volatility, which is calculated as IV*(1-BL). BL is book leverage. $1_{ret<0}$ ($1_{ret>0}$) is a dummy variable which is equal to one when the stock return is positive (negative). Idiosyncratic volatility (IVol) is the standard deviation of the residuals of Fama-French three factor model estimated using the daily return over the previous month. Size_a is the logrithm of the firm's asset. Option Illiquidity is the difference between bid and ask option price divided by the avereage of bid and ask price. Reported are coefficients and Dama-MacBeth t-statistics with Newy-West correction for serial correlation.

Table 8: Returns of selling delta-hedged options: Double sorting on size and leverage

	1-BL	2	3	4	5-BL	5-1	t-stat
Panel A: ATM Call							
1-size	2.28	2.44	2.32	2.41	2.72	0.44***	2.78
2	1.68	1.61	1.72	2.05	2.1	0.42***	4.19
3	1.64	1.53	1.38	1.69	2.03	0.39***	4.16
4	1.45	1.38	1.32	1.64	1.66	0.22**	2.36
5-size	1.18	1.09	1.09	1.24	1.07	-0.1	0.8
Panel B: OTM Call							
1-size	2.7	2.8	2.81	2.98	3.57	0.88***	4.81
2	2.17	2.11	2.44	2.57	2.53	0.36**	2.56
3	2.08	1.92	2.01	2.28	2.57	0.49***	4.01
4	1.93	1.68	1.96	2.27	2.38	0.45***	3.87
5-size	1.66	1.64	1.64	1.65	1.78	0.12	0.89
Panel C: ATM Put							
1-size	2.5	2.51	2.31	2.38	2.99	0.49***	4.79
2	1.88	1.82	1.73	1.97	2.01	0.13	1.46
3	1.73	1.32	1.48	1.67	2.15	0.42***	5.4
4	1.55	1.36	1.38	1.44	1.67	0.12	1.21
5-size	1.12	1.07	1.1	1.19	1.21	0.09	1
Panel D: OTM Put							
1-size	2.85	2.8	2.79	2.86	3.61	0.76***	5.25
2	2.01	2.02	1.99	2.34	2.36	0.35***	2.83
3	2.13	1.75	1.81	2.09	2.61	0.48***	3.83
4	1.94	1.55	1.71	1.8	2.28	0.34***	3.35
5-size	1.51	1.55	1.54	1.69	1.76	0.24**	2.04

Note: This table reports the average returns pf delta-hedged options on stocks of different size and leverage level. At the end of each month, the optionable stocks are first sorted into five quintiles based on their asset size, and then within each size quintile, they are further sorted into five quintiles by leverage ratio. The results for ATM call, OTM call, ATM put and OTM put are presented in Panel A to Panel D. The t statistics are corrected for seriabl correlation (Newey-West correction with 2 lags for monthly return). The sample dates from January 1996 to August 2014.

Table 9: Returns of selling delta-hedged options: Double sorting on asset volatility and leverage

	1-BL	2	3	4	5-BL	5 _1	t-stat
Panel A: ATM Call							
1-Asset Vol	0.75	1.04	1.41	1.41	1.63	0.88***	7.92
2	0.89	1.03	1.11	1.61	2.29	1.40***	14.19
3	1.13	1.21	1.45	1.67	2.62	1.48***	14.63
4	1.22	1.53	1.58	1.8	2.7	1.48***	12.48
5-Asset Vol	2.26	2.44	2.22	2.48	3.23	0.98***	6.69
Panel B: OTM Call							
1-Asset Vol	1.25	1.45	2.07	2.15	2.28	1.03***	8.55
2	1.17	1.5	1.73	2.22	2.83	1.66***	10.07
3	1.62	1.85	2.05	2.4	2.99	1.36***	10.17
4	1.74	1.98	2.1	2.31	3.24	1.50***	10.6
5-Asset Vol	2.64	2.81	2.72	2.97	4.03	1.39***	8.41
Panel C: ATM Put							
1-Asset Vol	0.66	0.95	1.36	1.39	1.84	1.18***	14.61
2	0.85	0.9	1.17	1.48	2.3	1.45***	17.87
3	1.12	1.18	1.47	1.71	2.5	1.37***	14
4	1.34	1.52	1.64	1.94	2.83	1.49***	14.21
5-Asset Vol	2.48	2.57	2.4	2.59	3.33	0.85***	5.96
Panel D: OTM Put							
1-Asset Vol	1	1.3	1.85	2	2.37	1.36***	12.9
2	1.35	1.35	1.48	1.97	2.87	1.53***	14.91
3	1.54	1.52	1.87	2	2.82	1.29***	9.52
4	1.52	1.66	1.99	2.08	3.48	1.96***	14.66
5-Asset Vol	2.87	2.99	2.54	3.12	3.77	0.90***	5.32

Note: This table reports the average returns pf delta-hedged options on stocks of different asset volatility and leverage level. At the end of each month, the optionable stocks are first sorted into five quintiles based on their asset volatility, and then for each size quintile, they are further sorted into five quintiles by leverage ratio. The results for ATM call, OTM call, ATM put and OTM put are presented in Panel A to Panel D. The t statistics are corrected for seriabl correlation (Newey-West correction with 2 lags for monthly return). The sample dates from January 1996 to August 2014.

Table 10: Robustness Check: Double sorting on size and leverage

	1-BL	2	3	4	5-BL	5 _1	t-stat
Panel A: ATM Call							
1-Asset Vol	0.75	1.01	1.36	1.32	1.38	0.63***	5.23
2	0.91	1.01	1.08	1.59	2.14	1.23***	12.35
3	1.14	1.21	1.44	1.63	2.53	1.39***	14.05
4	1.19	1.52	1.56	1.73	2.63	1.45***	11.59
5-Asset Vol	1.96	2.21	2.01	2.32	3.07	1.11***	7.6
Panel B: OTM Call							
1-Asset Vol	1.24	1.42	2.01	2.01	2.01	0.77***	6.24
2	1.2	1.49	1.68	2.19	2.7	1.51***	9.12
3	1.64	1.85	2.04	2.38	2.9	1.26***	9.23
4	1.7	1.95	2.07	2.23	3.12	1.42***	9.1
5-Asset Vol	2.34	2.62	2.44	2.79	3.81	1.48***	8.21
Panel C: ATM Put							
1-Asset Vol	0.66	0.91	1.28	1.28	1.62	0.96***	11.29
2	0.87	0.89	1.18	1.47	2.22	1.35***	16.38
3	1.14	1.19	1.45	1.69	2.43	1.29***	13.44
4	1.3	1.48	1.61	1.92	2.74	1.44***	12.3
5-Asset Vol	2.26	2.4	2.27	2.43	3.11	0.85***	5.19
Panel D: OTM Put							
1-Asset Vol	1.01	1.25	1.75	1.92	2.15	1.14***	10.16
2	1.37	1.31	1.51	1.97	2.76	1.39***	13.38
3	1.58	1.51	1.86	1.99	2.74	1.16***	8.72
4	1.44	1.6	1.92	2.01	3.38	1.94***	12.39
5-Asset Vol	2.68	2.84	2.4	2.93	3.46	0.77***	3.79

Note: This table reports the average returns pf delta-hedged options on stocks of different asset volatility and leverage level. At the end of each month, the optionable stocks are first sorted into five quintiles based on their asset volatility, and then within each size quintile, they are further sorted into five quintiles by leverage ratio. The results for ATM call, OTM call, ATM put and OTM put are presented in Panel A to Panel D. The t statistics are corrected for seriabl correlation (Newey-West correction with 2 lags for monthly return). The sample dates from January 1996 to August 2014.

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