Firm Leverage and Equity Option Returns *

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Abstract

This paper studies the effect of firm's capital structure on the delta-hedged equity option returns written on leveraged equity of the firm. Using a stylized capital structure model with jumps, we derive the expected return of a delta-hedged equity option. We show that, under realistic assumptions, delta-hedge option returns are negatively related to leverage and asset volatility. The empirical evidence is consistent with the model prediction. The results are robust to other determinants of option returns such as idiosyncratic volatility, historical minus implied volatility, and the volatility term structure.

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1 Introduction

Recent studies find that individual equity option returns are predicted by firm characteristics. Some of these characteristics are 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 the slope of the volatility term structure (Vasquez (Forthcoming)).

The goal of our paper is to use a Merton-type capital structure model to determine the firm's structural variables that predict equity option returns. In particular, we find that firm leverage and asset volatility are determinants of future equity option returns. We find that the effect of financial leverage is much larger and consistent with the model if the endogeneity of leverage is considered. Empirically, firm leverage and asset volatility are both negatively related with expected delta-hedged option returns, consistent with the prediction of the model.

A delta-hedged equity option position consists 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 (2003a) 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 (2003a), 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 factors. 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 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 (2003a) and Carr and Wu (2009b), 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 a stylized Merton-type capital structure model. In this model, the dynamic of the asset value of a firm follows a jump diffusion process. Based on this framework, we find that the expected return of delta-hedged equity option portfolio relates to several firm-level structural variables: the the leverage ratio of the firm, the asset volatility and the debt maturity. The result implies, after dynamically hedging out the option exposure to the underlying stocks, that 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.

There are two common sources of variance risk: stochastic volatility and jumps. We use a jump diffusion-type of model instead of a stochastic volatility model for one reason. We show that a stochastic volatility model for the underlying asset process produces an expected option return of zero. The main reason is that we price options on options or compound option, which models equity as an option of the asset process. Note that Bakshi and Kapadia (2003a) find a non-zero option return since they model equity and its stochastic volatility directly, not as an option on the asset. In our model, volatility risk in the underlying asset process can be hedged away by delta hedging the equity, which is an option written on the firm asset.

To test the implications of the model, we examine the cross-section of equity option returns in the US market. We pick one call (or put) option on each optionable stock at the end of each month and evaluate the return of the portfolio that buys one call (or put) that is daily delta-hedged with the underlying stock. The empirical results support 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 initial value of the portfolio. Second, we find that the ex-post variance risk premium during the life of the option can explain about 20% of the variation of the delta-hedged option return, both in the time-series and in the cross section. Third, after controlling for the anomaly variables such as the idiosyncratic volatility, the difference between realized volatility and implied volatility, and the slope of the volatility term structure, the delta-hedged option return is decreasing with leverage, asset volatility and debt maturity. 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. Fourth, the results are confirmed in the leverage-based trading strategies.

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 characteristics 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, investor overreaction, and option liquidity. Our paper departs from these papers along several dimensions. First, we are the first to show theoretically and empirically that firm's structural characteristics affect the delta-hedged option return. In particular, we show that firm leverage and asset volatility are negativelly related with expected option returns. Second, our findings augment the literature by showing that the financing decision of the firm plays a sizable role in generating cross-sectional variations in delta-hedged equity option returns. To the best of our knowledge, we are the first paper to identify theoretical determinants of expected delta-hedged equity option returns. Our paper is also related 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 our paper is different from theirs. Our paper contributes to the literature on the credit risk channel of the pricing of different derivatives on the underlying firm's asset. The notion that equity is a call option on the firm's asset goes back to Merton (1974). Following this philosophy, Geske (1979)

[1]See Goyal and Saretto (2009), Cao and Han (2013), Vasquez (Forthcoming), Christoffersen et al. (2014) and Cao et al. (2016).

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 et al. (Forthcoming) study the impact of leverage on the pricing of equity options. However, the models in these papers only assume one dimension of randomness in the underlying asset. Hence, they cannot explain the negative delta-hedged option returns. 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 a more realistic level of delta-hedged gain of the equity option portfolio can be generated. Some studies also confirm that equity options indeed contain information about a firm's default risk and provides evidence that supports such a credit risk channel, such as Hull et al. (2004), Carr and Wu (2009a), Carr and Wu (2011) and Culp et al. (2014). We differ from these studies in that we study the credit risk channel for understanding the equity option returns.

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 Delta-hedged equity option gain in a capital structure model

In this section, we derive the delta-hedged equity option gain in a stylized capital structure model. Bakshi and Kapadia (2003a) show that the expected delta-hedged option gain is zero for all one-dimensional Markov price process. As illustrated in Todorov (2010), there are two sources of market variance risk: the presence of stochastic volatility and the occurrence of unanticipated jumps. Hence, to generate non-zero expected delta-hedged gain for equity options as documented in Bakshi and Kapadia (2003b), Goyal and Saretto (2009), and Cao and Han (2013), we specify the underlying asset value with a basic jump diffusion process. In the Appendix, we discuss why stochastic volatility model is not appropriate to generate non-zero delta-hedged equity option gain in a compound option pricing model.

2.1 The process of firm asset and equity

We start with specifying the process of the firm's asset value. We consider a firm whose asset value V_t follows a 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 W_t is a standard Brownian process, N_t follows a Poisson distribution with jump intensity λ and J_i is the jump size which is a random variable with mean μ_j and variance σ_j^2. We further assume that the jump risks related to the jump intensity λ and the jump size J_i are priced. Hence, after change of measure, the asset value V_t has the following process under the risk neutral measure Q:

$$\frac{dV_t^Q}{V_t^{Q-}} = rdt + \sigma dW_t + d(\sum_{i=1}^{N_t^Q}(J_i^Q - 1)), \tag{2}$$

where N_t^Q and J_i^Q represent the number of jumps and the jump size of the asset return under the risk neutral measure.

Suppose that the firm issues two classes of claims: equity and debt. On the specified calendar date T, the firm promises to pay a total of D dollars to the bondholders. In the event this payment is not met, the bondholders immediately take over the company and the shareholders receive nothing. The debt is assumed not to have coupon nor embedded option feature. Default can be triggered only at maturity and this occurs when $V_t < D$. In addition, the firm cannot issue any new senior claims on the firm nor can it pay cash dividends or do share repurchase prior to the maturity date of the debt. The equity of the firm can then be considered a call option written on the asset of the firm with D as the strike price and T as maturity.

The value of the equity can be expressed as the discounted expected payoff under the risk neutral measure: $S_t = E^Q[e^{-rt}\max(V_t - D, 0)]$. Under the risk neutral measure Q, the process of the equity value can be obtained by the Ito's formula:

$$dS_t^Q = \frac{\partial S_t}{\partial V_t}(dV^Q)^c + \frac{1}{2}\frac{\partial^2 S_t}{\partial V_t^2}\sigma^2 V_t^2 dt + d\sum_{i=1}^{N_t^Q}(S(V_t) - S(V_{t-})),$$

where $(dV^Q)^c = V_t^-(rdt + \sigma dW_t^Q)$ is the continuous component of dV under the risk neutral measure. Rewriting the process in terms of $\mu_{S_t}^Q$ and σ_{S_t}, we have

$$\frac{dS_t^Q}{S_t^Q} = \mu_{S_t}^Q dt + \sigma_{S_t} dW_t^Q + d\sum_{i=1}^{N_t^Q}(S(V_t) - S(V_{t-})), \tag{3}$$

where $\sigma_{S_t} = \frac{\partial S_t}{\partial V_t}\frac{V_t}{S_t}\sigma$ and $\mu_S^Q = r - \frac{\lambda^Q}{S_t}E^Q[S(V) - S(V-)]$, because the discounted equity price process is a martingale under the risk neutral measure. This stylized capital structure model features the leverage effect through the expression of the stock volatility $\sigma_{S_t} = \frac{\partial S_t}{\partial V_t}\frac{V_t}{S_t}\sigma$: if the stock price moved downwards, the market leverage of the firm $\frac{D}{S_t}$ and the stock volatility σ_{S_t} increases, which in turn produces the contemporaneous negative relation between stock return and stock volatility. Under the physical measure, the stochastic process of the equity value is obtained by Ito's lemma:

$$dS_t = \frac{\partial S_t}{\partial V_t}dV_t^c + \frac{1}{2}\frac{\partial^2 S_t}{\partial V_t^2}\sigma^2 V_t^2 dt + d\sum_{i=1}^{N_t}(S(V_t) - S(V_{t-})), \tag{4}$$

where $dV^c = V_t^-(\mu dt + \sigma dW_t)$ is the continuous component of dV and $S(V) - S(V_-)$ is the jump size of the equity value when a jump in the asset process occurs.

2.2 Delta-hedged returns of options on the levered equity

We now turn to the valuation of options written on the levered equity and expected gain of the delta-hedged option portfolio. The payoffs of the call and put options at maturity are $\max(S_t(V_t) - K, 0)$ and $\max(K - S_t(V_t), 0)$ respectively. The value of an European option on equity $S(V)$ at time 0 maturing at t, with strike price K is equal to,

$$O(0,t;K) = e^{-rt}E^{Q}[\text{Max}(S_t - K, 0)],$$

To remove the impact of the underlying stock movement on the option returns, we consider the return of 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 price. The delta-hedged gains net of the risk-free rate earned by the portfolio is defined as,

$$\Pi_{0,t} = O_t - O_0 - \int_0^t \Delta_u dS_u - \int_0^t r(O_u - \Delta_u S_u)du, \tag{5}$$

where O_t is the option price at time t, $\Delta_t = \frac{\partial O_t}{\partial S_t}$ is the delta of the option, and r is the risk free rate. By Ito's lemma, under the physical distribution, the option price can be written as

$$O_t = O_0 + \int_0^t \frac{\partial O}{\partial u}du + \int_0^t \frac{\partial O_u}{\partial S_u}dS_u^c + \frac{1}{2}\int_0^t \frac{\partial^2 O_u}{\partial S_u^2}dS_u^c dS_u^c + \sum_{0<u<t}(O(S_u) - O(S_{u-})) \tag{6}$$

where dS_u^c is the continuous part of dS_u. The last part in equation (6) 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.

Given that 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 given based on Equation 3:

$$rO_t = \frac{\partial O_t}{\partial t} + \frac{\partial O_t}{\partial S_t}\mu_{S_t}^{Q}S_t + \frac{1}{2}\frac{\partial^2 O_t}{\partial S_t^2}(\sigma_{S_t}^{Q})^2 S_t^2 + \lambda^{Q}E^{Q}[O(S_t) - O(S_{t-})]. \tag{7}$$

Combining equations (6) and (7), the option price can be expressed as

$$\begin{aligned} O_t = O_0 + \int_0^t \frac{\partial O_u}{\partial S_u}dS^c + \int_0^t (rO_u - \frac{\partial O_u}{\partial S_u}\mu_S^{Q}S_u - \lambda^{Q}E^{Q}[O(S_u) - O(S_{u-})])dt \\ + \sum_{0<u<t}(O(S_u) - O(S_{u-})). \end{aligned} \tag{8}$$

where $\mu_S^Q = r - \frac{\lambda^Q}{S_t} E^Q[S(V) - S(V-)]$. Therefore, the expected delta-hedged gain is equal to

$$
\begin{aligned}
E(\Pi_t) &= E(O_t - O_0 - \int_0^t \frac{\partial O_u}{\partial S_u} dS_u - \int_0^t r(O_u - \frac{\partial O_u}{\partial S_u} S_u du)) \\
&= \int_0^t \{-\lambda^Q E^Q[O(S_u) - O(S_{u-})] + \lambda^Q E^Q[(S(V) - S(V_-))\frac{\partial O_u}{\partial S_u}] \\
&\quad - \lambda E[(S(V) - S(V_-))\frac{\partial O_u}{\partial S_u}] + \lambda E[O(S_u) - O(S_{u-})]\} dt.
\end{aligned}
\tag{9}
$$

Note that the dS_u term in the first line of Equation (9) is the total change in the stock price including both the continuous and discontinuous parts. The following proposition shows the expression of the expected delta-hedged gains in terms of the option gamma, the asset beta, the asset variance and the stock price. More details of the derivation are provided in Appendix A.1.

Proposition 1 *Let the firm's asset price process under the physical and risk neutral measures follow the dynamics given in equations (1) and (2), with an equity process of the firm given in equation (4) and (3). The expected delta-hedged gain can be expressed as*

$$
E(\Pi_t) \approx \int_0^t \frac{1}{2} \frac{\partial^2 O_u}{\partial S_u^2} \beta_v^2 \left((\sigma_v^P)^2 - (\sigma_v^Q)^2\right) S_u^2 du \tag{10}
$$

where $\frac{\partial^2 O}{\partial S^2}$ *is the gamma of the option,* $\beta_v = \frac{\partial S_u}{\partial V_u}\frac{V_u}{S_u}$, $(\sigma_v^P)^2 = \sigma^2 + \lambda E[J-1]^2$ *and* $(\sigma_v^Q)^2 = \sigma^2 + \lambda^Q E^Q[J-1]^2$.

From Proposition 1, the expected delta-hedged option gain is directly related to option gamma, the square of asset beta β_v^2, the variance risk premium of the underlying asset process $(\sigma_v^P)^2 - (\sigma_v^Q)^2$ and the square of stock price S_u^2. β_v is a measure of elasticity or leverage in the option literature, when we consider the equity value S_t as an option on the underlying asset value. This measure represents percentage change in option price for a one percentage change in the underlying price. It is called the "embedded leverage" in Frazzini and Pedersen (2012). In the Appendix, we show that the delta-hedged option gain and the variance risk premium of the equity are related in the following equation:

$$E(\Pi_t) \approx \int_0^t \frac{1}{2} \frac{\partial^2 O_u}{\partial S_u^2} \frac{dVRP}{dt} S_u^2 du. \tag{11}$$

Under the special case that the variance risk premium of the underlying asset is a linear function of variance as in Bakshi and Kapadia (2003a), where $(\sigma_v^P)^2 - (\sigma_v^Q)^2 = k(\sigma_v^P)^2$ and k measures price of jump risk and the exposure to the market jump risk, the delta-hedged gain is rewritten as:

$$E(\Pi_t) \approx \int_0^t \frac{1}{2} \frac{\partial^2 O_u}{\partial S_u^2} \, \beta_v^2 \, k(\sigma_v^P)^2 \, S_u^2 du \tag{12}$$

Hence, the relation between the delta-hedged option gain and firm characteristics depends on the sign of k. Bakshi and Kapadia (2003a) show that k is significantly negative for the SP500 index options which represents a negative variance risk premium. Moreover, evidence in Bakshi and Kapadia (2003b), Goyal and Saretto (2009), and Cao and Han (2013) support a significantly negative k in the cross section of equity options. Hence, we assume k is negative in the following otherwise specified.

2.3 The role of leverage and asset volatility in the expected delta-hedged gain

Proposition 1 shows that the option gamma and firm characteristics such as asset volatility and asset beta can affect the delta-hedged gain in our model. However, to understand how firm's capital structure affect option gamma and asset beta, we need the analytic form of these two terms. Since the analytic forms of the option gamma and asset beta in terms of financial leverage are not available under the compound option pricing model with jumps, we resort to the Black-Scholes model. The magnitude of the impact of the financial leverage on option gamma and asset beta is different under these two types of models. However, whether it has a positive or negative effect on option gamma and asset beta should be qualitatively the same. Under the Black-Scholes model where equity option is an option on the equity, the option gamma is expressed as:

$$\frac{\partial^2 O}{\partial S^2} = Ke^{-rt}\frac{\phi(d_2)}{S_t^2 \sigma_S \sqrt{t}},$$

where $d_2 = \frac{ln(S_t/K)+(r-\sigma_S^2/2)t}{\sigma_S\sqrt{t}}$ and $\phi(x) = e^{-\frac{x^2}{2}}/\sqrt{2\pi}$. In addition, the volatility of the stock return and the asset return has the following relation: $\sigma_S = \frac{\partial S}{\partial V}\frac{V}{S} = \beta_v \sigma_v$. Substituting the expression of option gamma in Equation (12), we get

$$\frac{E(\Pi_t)}{S_0} \approx \int_0^t \frac{1}{2}\frac{K}{S_0}e^{-rt}\frac{\phi(d_2)}{\sqrt{t}}\,\beta_v\, k\sigma_v^P\ du \tag{13}$$

Given the level of asset volatility σ_v^P and the asset value of the firm V_t, the firm's capital structure affects the delta-hedged gain of the option portfolio through asset delta $\beta_v = \frac{\partial S}{\partial V}\frac{V}{S}$ and $\phi(d_2)$. In a Black-Scholes model, $\beta_v = \Phi(d_{v1})\frac{V_t}{S_t}$, where $d_{v1} = \frac{ln(V_t/D)+(r+\sigma_v^2/2)T}{\sigma_v\sqrt{T}}$. When the debt of the firm increases, $\frac{V_t}{S_t}$ increases and $\Phi(d_{v1})$ decreases, where the change of S_t as the first order effect dominates. Hence, the asset beta is increasing in D, similar as in Merton (1974). The other term in Equation (13) $\phi(d_2) = e^{-\frac{d_2^2}{2}}/\sqrt{2\pi}$ is also increasing in D:

$$\frac{\partial\phi(d_2)}{\partial D} = \frac{\partial\phi(d_2)}{\partial\sigma_S}\frac{\partial\sigma_S}{\partial\beta_v}\frac{\partial\beta_v}{\partial D} > 0.$$

Another feature in the capital structure of the firm, the maturity time of the debt T, also affects asset beta and $\phi(d_2)$. When the maturity time of the debt T increases, $\frac{V_t}{S_t}$ decreases and $\Phi(d_{v1})$ increases, where the change of S_t as the first order effect dominates. As a result, asset beta β_v is decreasing in T. Moreover, $\phi(d_2)$ is decreasing in T:

$$\frac{\partial\phi(d_2)}{\partial T} = \frac{\partial\phi(d_2)}{\partial\sigma_S}\frac{\partial\sigma_S}{\partial\beta_v}\frac{\partial\beta_v}{\partial T} < 0.$$

Hence, other things being equal, the shorter the debt maturity, the more negative the delta-hedged scaled gain if k is negative. In other words, firms with higher short term debt ratio should have a more negative delta-hedged scaled gain.

Next, we discuss the effect of asset volatility on $\beta_v\sigma_v^P$ and $\phi(d_2)$. In the Black-Scholes model, the first item is $\Phi(d_{v1})\frac{\sigma_v^P V_t}{S_t}$. $\Phi(d_{v1})$ and S_t are both increasing in σ_v^P, but the effect of

σ_v^P on the numerator dominates the effect of S_t in the denominator. Hence, $\beta_v \sigma_v^P$ and $\phi(d_2)$ are both increasing in σ_v^P. Proposition 2 summarizes the discussion of the relation between the firm characteristics and expected delta-hedged gain when k is negative.

Proposition 2 *The scaled delta-hedged gain* $\frac{E(\Pi_t)}{S_0}$ *is decreasing in the face value of the debt D, decreasing in asset volatility* σ_v^P *and increasing in debt maturity T.*

The capital structure of a firm can be measured by market leverage ($ML = \frac{D}{S_t}$) or book leverage ($BL = \frac{D}{V-D}$). The market leverage is affected by the change of the face value of the debt (D) and the change of the market price of the equity (S_t). If the stock price S_t decreases, through the leverage effect embedded in our model, β_v and σ_S increases, which increases the riskiness of the stock and $\phi(d_2)$. Thus, in the short run, when the fluctuations in the stock price are the main determinants of variations in the market leverage, market leverage is more correlated with the scaled delta-hedged gain than the book leverage, which is not affected by the movement of the stock price. Proposition 3 describes the difference of market leverage and book leverage on expected delta-hedged gain.

Proposition 3 *Due to the leverage effect, the impact of the market leverage on the scaled delta-hedged gain* $\frac{E(\Pi_t)}{S_0}$ *is stronger than that of the book leverage.*

While the evidence in the literature shows that k is on average negative for the equity options, the variance risk premium could be positive for some stocks in some periods in a large cross section of firms. In addition, studies such as Bakshi et al. (2003) and Carr and Wu (2009b) show that the variance risk premium in the individual options are less negative than that in the index options. Consequently, the relation of firm characteristics and expected delta-hedged gain could be different when k is negative and k is positive. The effect of k is summarized in the following proposition.

Proposition 4 *If k is negative, the scaled delta-hedged gain is decreasing in firm leverage and asset volatility. If k is positive, the scaled delta-hedged gain is increasing in firm leverage and asset volatility.*

2.4 The endogeneity issue of the firm's leverage

In the model presented earlier in this paper, firm's leverage is exogenously given for a specific firm, similar as in Merton (1974). If the shareholders can potentially maximize the total value of the firm by choosing the optimal leverage level, such as in the model of Leland and Toft (1996), firm's capital structure depends on the underlying asset risk (asset volatility), taxes, and bankruptcy costs, etc. Intuitively, the endogeneity issue of leverage induces negative correlation between the underlying asset risk (asset volatility) and leverage. Namely, leverage decreases with asset volatility, because firm with low asset volatility exploit the tax advantage of debt while maintaining a low cost of financial distress. The endogeneity of leverage has been widely confirmed in the empirical literature, such as in Harris and Raviv (1991), Molina (2005) and Bartram et al. (2015). A recent study by Choi and Richardson (2016) shows that the true impact of leverage on equity volatility is much larger after controlling asset volatility.

In the context of this paper, the endogeneity of leverage occurs because leverage and delta-hedged option return are both affected by exogenous and unobservable shocks to the firm's fundamental risk. Ignoring the endogenous nature of leverage can lead to an underestimation of its effect on the delta-hedged option return, and consequently to an under-estimation of the uncertainty risk premium of the firm. In fact, the empirical results suggest that the effect of leverage on the delta-hedged option return is substantially stronger when the asset volatility is controlled.

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 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 delta, gamma, vega, theta, and rho. The implied volatility and greeks are computed using an algorithm based on the Cox et al. (1979) model. If the option price is not available for any given day, we use the most recent valid price. We also obtain the risk free rate from OptionMetrics. Financial firms are excluded from the analysis since conventional capital structure models cannot explain their financing decisions.

At the end of each month and for each optionable stock, we collect the call and put options that are closest to being at-the-money and have the shortest maturity among those with more than one month to expiration. We also apply the following filters to select the options. First, to mitigate the problem of early exercise feature of American options, we only include the options if the underlying stock does not pay dividends during the remaining life of the option. Second, prices that violate arbitrage bounds are eliminated. Third, an observations is eliminated if any of 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), or (iv) there is no volume or open interest.

The delta-hedged option position is constructed by holding a long position in an option, hedged by a short position of delta shares on the underlying stock. The definition of delta-hedged option gain follows Bakshi and Kapadia (2003a) and is given by

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

where C_t represents the price of an European call option at time t, $\Delta_u = \frac{\partial C_u}{\partial S_t}$ is the option delta at time u, and 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 date t_n, $n = 0, 1, ...N-1$. As shown by Bakshi and Kapadia (2003a) in a simulation setting, the use of the Black-Scholes hedge ratio has a negligible bias in calculating delta-hedged gains. The discrete delta-hedged call option gain up to the maturity date $t+\tau$ is defined as

$$\begin{aligned}\Pi_{t,t+\tau} = {} & \max(S_{t+\tau} - K, 0) - C_t \\ & - \sum_{n=0}^{N-1} \Delta_{t_n} [S_{t_{n+1}} - S_{t_n}] - \sum_{n=0}^{N-1} r_n (C_t - \Delta_{t_n} S_{t_n}) \frac{\tau}{N}.\end{aligned} \tag{14}$$

The definition for delta-hedged put option gain is similar to equation (14), except that the option price and delta are for the put option and the payoff of the put option 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.

Equation (13) shows that one determinant of the delta-hedged option gain is the volatility of the underlying asset process. We estimate the asset volatility at the end of each month using the iteration procedure based on Merton's Model, following Vassalou and Xing (2004) and Bharath and Shumway (2008).

3.2 Balance sheet data

Balance sheet data are obtained from Compustat database. Market (Book) leverage 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 market (book) equity. 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 market equity. Book to market ratio is defined as book equity divided by market equity.

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 Control variables

The main control variables are idiosyncratic volatility, slope of the volatility term structure, volatility deviation, size, book to market and bid-ask spread. 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). Volatility deviation is defined as the difference between historical volatility over the previous year and at-the-money implied volatility, following Goyal and Saretto (2009). Following Vasquez (Forthcoming), the slope of the volatility term structure is defined as the difference between the average of at-the-money call and put implied volatilities with 365 and 30 days to maturity. 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: $(2(O_{bid} - O_{ask})/(O_{bid} + O_{ask})$, where O_{bid} is the highest closing bid price and O_{ask} is the lowest closing ask price.

3.4 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. Table 1 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 detailed information for the delta-hedged option returns under the two categories are presented in Table 1.

4 Cross sectional regression analysis

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

4.1 Delta-hedged option return and ex-post variance risk premium

In equation (11), we show that the delta-hedged option return is related to stock characteristics because it captures the equity variance risk premium during the life of the option before expiration. Hence, in the first step, we test the relation between the two and examine how much the delta-hedged option return can be explained by the equity variance risk premium, both in the cross section and in the time series regressions. In the previous literature, the ex-ante variance risk premium is often used to control for the variance risk embedded in the delta-hedged option return. However, it is a solid proxy of variance risk only if the ex-ante variance risk premium is a unbiased estimator of the ex-post variance risk premium. Different from the previous literature, we examine how much the delta-hedged option return can be explained by the ex-post variance risk premium accumulated during the holding period. As is shown in equation (11), the option gamma affects the reflection of variance risk premium in the delta-hedged option return. If the the level of the option gamma is too small and time varying, it is likely that these options have little information about the nature of the variance risk premium. Hence, we select options with gamma larger than 0.07.

Table 3 shows the regression results of cross-sectional and time-series regression. In the cross-section regression, the average number of firms is 990 each month. In the time-series regression, we select firms with more than 30 observations of delta-hedged option return. The results shows that the ex-post variance risk premium and option gamma can explain around 21% of the variation of the delta-hedged option returns both in the cross section and in the time series.

4.2 Leverage, asset volatility and delta-hedged option returns

We study the relation between leverage, asset volatility and delta-hedged option returns using monthly Fama-Macbeth regressions. In Table 4, we show the benchmark regression results with market leverage and book leverage. The delta-hedged gain is scaled by initial stock price in Panel A and scaled by the initial capital of the delta-hedged option portfolio in Panel B. First, the result confirms the endogenous issue of the leverage variable in Molina (2005) and Choi and Richardson (2016). The market leverage has no significant impact on the delta-hedged option return in the univariate Fama-French regression. However, after controlling for the underlying risk of the firm measured by asset volatility, we identify a significantly negative relation between market leverage and delta-hedged option return with average t statistics -4.25 and -3.81. Second, consistent with the discussion in Proposition

3, we find a weaker relation for the book leverage. Third, the coefficients of market leverage are significantly negative whether we scale the delta-hedged gain by initial stock price or by initial capital. The average t statistics is slightly higher when it is scaled by initial stock price, consistent with the discussion in Section 2.3. In the following analysis, we focus on the role of market leverage in determining the cross sectional variation of the delta-hedged option return. To be comparable with the results in the previous literature such as in Goyal and Saretto (2009) and Cao and Han (2013), we use the delta-hedged option return scaled by the initial capital in the following tables.

Table 5 shows that both leverage and asset volatility are significantly negative and robust in all specifications, consistent with the implications in the model. In model (2) to (8), we control for the variables that can predict future delta-hedged option return in the literature: idiosyncratic volatility (Cao and Han (2013)), the slope of the volatility term structure (Vasquez (Forthcoming)), the log difference of realized and implied volatility (Goyal and Saretto (2009)), size and market to book ratio (Cao et al. (2016)), and the bid-ask spread ((Christoffersen et al., 2014)). The coefficients of leverage and asset volatility are still statistically significant and stable after controlling for these variables, showing that the relation cannot be explained by the the limits to arbitrage, market imperfections, volatility-related mispricing or liquidity.

Equation (12) in Section 2.3 suggest that the relation between leverage and delta-hedged option gain can be alternatively identified by using the delta hedged option return scaling by the square of asset volatility. Table 6 shows the regression results for delta-hedged option return divided by the square of asset volatility. We find that leverage is significantly negative in all specifications without controlling asset volatility. The results in Table 5 and Table 6 also show that the market leverage and asset volatility are not able to explain the anomalies documented in the literature in a linear model.

4.3 Debt maturity and delta-hedged option returns

As suggested in Section 2.3, debt maturity is positively related to the delta-hedged option return. This means that firms with the shorter debt maturity have more negative the delta-hedged option return, other things equal. In other words, firms with more short term debt scaled by the total debt should have more negative delta-hedged option return after controlling for market leverage and asset volatility. We, therefore, use the ratio of long-term debt due in one year to total debt as the short term debt ratio (CVNT1) and the ratio of long-term debt due within five years to total debt as the long-term debt ratio (CVNT5).

The effect of debt maturity is similar as the covenant effect studied in Toft and Prucyk (1997), in which the maturity structure of the firm's debt is 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 that equals the market value of debt on the issue date. Long-term debt, on the other hand, should have a smaller effect compared to the short-term debt. 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.

Table 7 reports the results of regressing the delta-hedged option return on the short term debt ratio and long term debt ratio (CVNT1 and CVNT5). First, we find that, in the different specifications, the estimated coefficient of both short term debt ratio and long term debt ratio are significantly less than zero after controlling for leverage and asset volatility. The estimated coefficients range from -0.011 to -0.028 and the t statistics range from -2.28 to -9.60.

Second, short-term debt ratio (CVNT1) has a larger effect on the delta-hedged option returns than the longer-term debt ratio (CVNT5). This pattern shows in all four samples, for instance, the estimated coefficient of cvnt1 (-0.028) is twice as large as that of cvnt5 (-0.014). 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. Overall, the results present in Table 7 support the hypothesis predicted in the theoretical model.

5 Leverage-based trading strategy

We now investigate the cross-sectional relation between delta-hedged option returns using portfolio sorting approach. This section proposes a leverage-based trading strategy and confirms the Fama-Macbeth regression results in the previous section.

5.1 Single sort portfolio

At the end of each month, we sort stocks with traded options into five quintiles based on their market leverage ratio. We then construct the delta-hedged option portfolio on the first trading day of the next month. Using the insights in the results of Table 6 and the discussion in Section 4.2, we scale the delta-hedged option return by the square of asset volatility times 10. Table 8 shows the average return of the portfolios for the five quintiles and the return of the difference in the fifth and the first quintile. We present results for equally weighted, open interest weighted and value weighted portfolio returns sorting on market leverage and book leverage. For all six specifications, the difference between the fifth and the first portfolio is always significantly negative. This table confirms that after scaling for asset volatility, the higher the leverage ratio, the more negative the delta-hedged option return.

5.2 Exposure of the long-short portfolio to the common factors

Table 9 examines how the return of our long-short leverage-based option strategy can be explained by the systematic volatility risk factors and higher-order market factors. We regress the time series of equal-weighted monthly returns of our market leverage-based option strategy on several systematic volatility riskfactors. The first is the delta-hedged option return of S& P500 index scaling by its implied variance times 10 (DHMKT),which proxies for the market variance risk (e.g., Coval and Shumway (2001); Bakshi and Kapadia (2003a)). The second is the market return minus risk free rate (MKTRF). The third to fifth factors are Fama-French three factors: SMB, HML and UMD. The remaining factors are higher order risk factors based on DHMKT and MKTRF.

The partial equilibrium capital structure model in our paper implies that the relation between firm leverage and delta-hedged option return is theoretically explained by firm's exposure to the common risk factors. Hence, the relation documented in our paper should not be considered as a new anomaly. We expect that the return of the long-short leverage portfolio is positively related to the market risk factors. Table 9 shows that the return of the long-short portfolio is significantly related to the market delta-hedged option return with estimated coefficients ranging from 0.385 to 0.707 in different specifications. The long-short return is in general not exposed to SMB, HML and UMD. The square of DHMKT, the cube of DHMKT and the square of MKTRF are significant in some of the specifications, which means that the long-short return exposes to higher order risk factors. Meanwhile, we should recognize that the alpha of the models are significant in all specifications. Hence, the market factors can only explain part of the time series variation of the long-short portfolio return, which might be due to the non-linearity of the portfolio return caused by leverage.

5.3 Double sort portfolios

In Table 6, we use Fama-Macbeth regressions to show that the negative relation between delta-hedged option return and leverage ratio is robust after controlling for anomalies suggested in the literature. Table 10 uses the double sort to confirm the regression result. At the end of each month, we first sort the stocks into five quintiles by the stock characteristics such as idiosyncratic volatility, slope of volatility term structure, volatility deviation and size. Within each quintile, the stocks are further sorted into five quintiles by their market leverage. Similar as in Table 6, the delta-hedged option return is scaled by the square of asset volatility times 10. We find that the effect of leverage is significant for 4 out of 5 quintiles sorted by idiosyncratic volatility and for 3 out of 5 quintiles sorted by slope of volatility term structure. The return difference between the fifth and first portfolio is larger for stocks with smaller volatility deviation. Since volatility deviation is a measure of investor overreaction in Goyal and Saretto (2009), this finding is consistent with the rational model in our paper. We also find that the return difference is much larger and more significant for smaller firms. The explanation is that leverage is a better measure of firm risk for smaller firms than larger firms.

Table 11 reports the average returns of delta-hedged options on stocks of different leverage levels after controlling for different characteristics. At the end of each month, the optionable stocks are first sorted into five quintiles based on the the firm characteristics, and then within each quintile, they are further sorted into five quintiles by leverage ratio. The leverage portfolios are averaged over each of the five characteristic portfolios. Results show that the returns of the long short leverage-based portfolio after controlling for idiosyncratic volatility, the slope of the volatility term structure, size and liquidity are statistically significant at 1%. The monthly return ranges from -2.66% to -3.19%.

6 Conclusion

This paper argues in a capital structure model that, firm's leverage ratio and asset volatility are two important 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 stylized capital structure model, in which the asset value of a firm is driven by a jump-diffusion process. In the model, the expected return of the delta-hedged equity option is closely linked to firm characteristics such as leverage, asset volatility and debt maturity through the channel of variance risk premium. Empirically we find that the ex-post variance risk premium can explain a large portion of the cross sectional and time series variation of the delta-hedged option return. We also find that leverage and asset volatility are significantly related to the delta-hedged option return in different specifications. The results are robust after controlling for anomalies variables documented in the literature, such as idiosyncratic volatility, the log difference between realized volatility and implied volatility, the slope of the volatility term structure and liquidity. Meanwhile, the anomalies cannot be explained by firm leverage and asset volatility in the linear Fama-Macbeth regression.

However, we show that the predictability of some firm characteristics documented in Goyal and Saretto (2009), Cao and Han (2013) and Cao et al. (2016) can be partially explained after we "de-lever" the delta-hedged option return in a way suggested in the model. Specifically, if we scale the delta-hedged option portfolio gain by the square of asset beta times square of stock price times option gamma, the predictability of anomalies variables become much weaker or even not significant.

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. The empirical evidence is in general consistent with the model. The implications of the model helps us understand the cross sectional variation of the delta-hedged equity option returns.

References

Andrew Ang, Robert J Hodrick, Yuhang Xing, and Xiaoyan Zhang. The cross-section of volatility and expected returns. *The Journal of Finance*, 61(1):259–299, 2006.

Gurdip Bakshi and Nikunj Kapadia. Delta-hedged gains and the negative market volatility risk premium. *Review of Financial Studies*, 16(2):527–566, 2003a.

Gurdip Bakshi and Nikunj Kapadia. Volatility risk premiums embedded in individual equity options: Some new insights. *The Journal of Derivatives*, 11(1):45–54, 2003b.

Gurdip Bakshi, Nikunj Kapadia, and Dilip Madan. Stock return characteristics, skew laws, and the differential pricing of individual equity options. *Review of Financial Studies*, 16 (1):101–143, 2003.

Söhnke M Bartram, Gregory W Brown, and William Waller. How important is financial risk? *Journal of Financial and Quantitative Analysis*, 50(04):801–824, 2015.

Sreedhar T Bharath and Tyler Shumway. Forecasting default with the merton distance to default model. *Review of financial studies*, 21(3):1339–1369, 2008.

Tim Bollerslev and Viktor Todorov. Tails, fears, and risk premia. *The Journal of Finance*, 66(6):2165–2211, 2011.

Tim Bollerslev, George Tauchen, and Hao Zhou. Expected stock returns and variance risk premia. *Review of Financial Studies*, 22(11):4463–4492, 2009.

Jie Cao and Bing Han. Cross section of option returns and idiosyncratic stock volatility. *Journal of Financial Economics*, 108(1):231–249, 2013.

Jie Cao, Bing Han, Qing Tong, and Xintong Zhan. Option return predictability. *Working Paper*, 2016.

Peter Carr and Liuren Wu. Stock options and credit default swaps: A joint framework for valuation and estimation. *Journal of Financial Econometrics*, page nbp010, 2009a.

Peter Carr and Liuren Wu. Variance risk premiums. *Review of Financial Studies*, 22(3): 1311–1341, 2009b.

Peter Carr and Liuren Wu. A simple robust link between american puts and credit protection. *Review of Financial Studies*, 24(2):473–505, 2011.

Jaewon Choi and Matthew Richardson. The volatility of a firm's assets and the leverage effect. *Journal of Financial Economics*, 121(2):254–277, 2016.

Peter Christoffersen, Ruslan Goyenko, Kris Jacobs, and Mehdi Karoui. Illiquidity premia in the equity options market. *Available at SSRN 1784868*, 2014.

Pierre Collin-Dufresne, Robert S. Goldstein, and Fan Yang. On the relative pricing of long-maturity index options and collateralized debt obligations. *The Journal of Finance*, 67(6): 1983–2014, 2012.

Joshua D Coval and Tyler Shumway. Expected option returns. *The journal of Finance*, 56 (3):983–1009, 2001.

John C Cox, Stephen A Ross, and Mark Rubinstein. Option pricing: A simplified approach. *Journal of Financial Economics*, 7(3):229–263, 1979.

KJ Martijn Cremers, Joost Driessen, and Pascal Maenhout. Explaining the level of credit spreads: Option-implied jump risk premia in a firm value model. *Review of Financial Studies*, 21(5):2209–2242, 2008.

Christopher L Culp, Yoshio Nozawa, and Pietro Veronesi. Option-based credit spreads. *Working Paper*, 2014.

Hitesh Doshi, Kris Jacobs, Praveen Kumar, and Ramon Rabinovitch. Leverage and the cross-section of equity returns. *Working Paper*, 2016.

Jan Ericsson, Kris Jacobs, and Rodolfo Oviedo. The determinants of credit default swap premia. *Journal of Financial and Quantitative Analysis*, 44(01):109–132, 2009.

Eugene F Fama and Kenneth R French. The cross-section of expected stock returns. *the Journal of Finance*, 47(2):427–465, 1992.

Andrea Frazzini and Lasse H Pedersen. Embedded leverage. 2012.

Robert Geske. The valuation of compound options. *Journal of Financial Economics*, 7(1): 63–81, 1979.

Robert L Geske, Avanidhar Subrahmanyam, and Yi Zhou. Capital structure effects on the prices of individual equity call options. *Journal of Financial Economics*, Forthcoming.

Ana González-Urteaga and Gonzalo Rubio. The cross-sectional variation of volatility risk premia. *Journal of Financial Economics*, Forthcoming.

Amit Goyal and Alessio Saretto. Cross-section of option returns and volatility. *Journal of Financial Economics*, 94(2):310–326, 2009.

Milton Harris and Artur Raviv. The theory of capital structure. *the Journal of Finance*, 46 (1):297–355, 1991.

Jing-Zhi Huang and Ming Huang. How much of the corporate-treasury yield spread is due to credit risk? *Review of Asset Pricing Studies*, 2(2):153–202, 2012.

John Hull, Izzy Nelken, and Alan White. Merton's model, credit risk, and volatility skews. *Journal of Credit Risk Volume*, 1(1):05, 2004.

Hayne E Leland. Corporate debt value, bond covenants, and optimal capital structure. *The Journal of Finance*, 49(4):1213–1252, 1994.

Hayne E Leland and Klaus Bjerre Toft. Optimal capital structure, endogenous bankruptcy, and the term structure of credit spreads. *The Journal of Finance*, 51(3):987–1019, 1996.

Robert C Merton. On the pricing of corporate debt: The risk structure of interest rates*. *The Journal of Finance*, 29(2):449–470, 1974.

Carlos A Molina. Are firms underleveraged? an examination of the effect of leverage on default probabilities. *The Journal of Finance*, 60(3):1427–1459, 2005.

Viktor Todorov. Variance risk-premium dynamics: The role of jumps. *Review of Financial Studies*, 23(1):345–383, 2010.

Klaus Bjerre Toft and Brian Prucyk. Options on leveraged equity: Theory and empirical tests. *The Journal of Finance*, 52(3):1151–1180, 1997.

Aurelio Vasquez. Equity volatility term structures and the cross-section of option returns. *Journal of Financial and Quantitative Analysis*, Forthcoming.

Maria Vassalou and Yuhang Xing. Default risk in equity returns. *The Journal of Finance*, 59(2):831–868, 2004.

Shu Yan. Jump risk, stock returns, and slope of implied volatility smile. *Journal of Financial Economics*, 99(1):216–233, 2011.

Chen Zhou and Xiao Xiao. The entropy based implied volatility and its information content. *Working Paper*, 2015.

A Appendix

A.1 Proof of Proposition 1: the expression of expected delta-hedged gain

The first part in equation (9) can be expanded into the first two terms in the Taylor expansion as an approximation:

$$E^Q[O(S) - O(S_-)] \approx E^Q[\frac{\partial O}{\partial S}(S - S_-) + \frac{1}{2}\frac{\partial^2 O}{\partial S^2}(S - S_-)^2]. \tag{15}$$

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

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

Substituting equation (15) and (16) into equation (9), we get equation (10) 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,

$$(S(V) - S(V_-))^2 \approx (\frac{\partial S}{\partial V}(V - V_-) + \frac{1}{2}\frac{\partial^2 S}{\partial V^2}(V - V_-)^2)^2. \tag{17}$$

There is quadratic, cubic and quartic terms in the above formula. Since higher order terms play a less important role, we only consider the first order term such that equation (10) is simplified as

$$\begin{aligned} E(\Pi_t) &\approx \int_0^t \frac{1}{2}\frac{\partial^2 O_u}{\partial S_u^2}(\frac{\partial S_u}{\partial V_u})^2(\lambda E[V_u - V_{u-}]^2 - \lambda^Q E^Q[V_u - V_{u-}]^2)du \\ &= \int_0^t \frac{1}{2}\frac{\partial^2 O_u}{\partial S_u^2}(\frac{\partial S_u}{\partial V_u})^2(V_{u-})^2(\lambda E[J-1]^2 - \lambda^Q E^Q[J-1]^2)du \end{aligned} \tag{18}$$

Note that the option price is a strictly convex function of the underlying asset price and that the 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 the stock price S is a call option on the firm's asset V. Recall that the total variances of the asset return under the physical and risk neutral measure are:

$$\begin{aligned}(\sigma_v^P)^2 &= \sigma^2 + \lambda E[J-1]^2 \\ (\sigma_v^Q)^2 &= \sigma^2 + \lambda^Q E^Q[J-1]^2 \end{aligned} \tag{19}$$

The expected delta-hedged gain can be rewritten as:

$$E(\Pi_t) \approx \int_0^t \frac{1}{2}\frac{\partial^2 O_u}{\partial S_u^2}(\frac{\partial S_u}{\partial V_u})^2 (V_{u-})^2((\sigma_v^P)^2 - (\sigma_v^Q)^2)du \tag{20}$$

$$= \int_0^t \frac{1}{2}\frac{\partial^2 O_u}{\partial S_u^2}\,\beta_v^2\,((\sigma_v^P)^2 - (\sigma_v^Q)^2)\,S_u^2 du \tag{21}$$

where $\beta_v = \frac{\partial S_u}{\partial V_u}\frac{V_u}{S_u}$

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,

$$[\log(S), \log(S)]_{(0,t]} = \int_0^t (\frac{\partial S_s}{\partial V_s}\frac{V_s}{S_s}\sigma)^2 ds + \sum_{0<s\leq t}(\frac{S_s - S_{s-}}{S_s})^2. \tag{22}$$

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,

$$\begin{aligned} VRP &= E^P[[\log(S), \log(S)]_{(0,t]}] - E^Q[[\log(S), \log(S)]_{(0,t]}] \qquad (23) \\ &\approx \int_0^t (\frac{1}{S_u})^2(\frac{\partial S_u}{\partial V_u})^2(\lambda E[V_u - V_{u-}]^2 - \lambda^Q E^Q[V_u - V_{u-}]^2)du \\ &= \int_0^t (\frac{V_u}{S_u})^2(\frac{\partial S_u}{\partial V_u})^2(\lambda E[J_u - 1]^2 - \lambda^Q E^Q[J-1]^2)du \end{aligned}$$

The second step uses the Taylor expansion in equation (17). If we ignore the movement in the stock price S, the variance risk premium is related to the delta-hedged option return by:

$$E(\Pi_t) = \int_0^t \frac{1}{2}\frac{\partial^2 O_u}{\partial S_u^2}\frac{dVRP}{dt}S_u^2 du. \tag{24}$$

A.2 Implication of the asset process with stochastic volatility

In this section, we include stochastic volatility in the asset process of the firm. We show that the stochastic volatility in the asset process does not generate any additional excess gain on the delta-hedged equity option portfolio.

We consider a firm with asset value V_t that follows a stochastic volatility process under the physical measure,

$$\frac{dV_t}{V_t} = \mu dt + \sqrt{\nu_t}dW_{1t}, \tag{25}$$

$$d\nu_t = \kappa(\theta - \nu_t)dt + \sigma\sqrt{\nu_t}dW_{2t} \tag{26}$$

The volatility of the asset return, ν, is driving by a diffusion process dW_{2t} that is correlated with dW_{1t} with constant correlation coefficient ρ. In the following derivation, we omit the subscript t in the notation.

If we consider equity of the firm as an option written on the firm's asset, then the equity value of the firm S is a function of V. By Ito's formula, we obtain

$$\begin{aligned} dS_t &= \frac{\partial S}{\partial t}dt + \frac{\partial S}{\partial V}dV + \frac{\partial S}{\partial \nu}d\nu + \frac{1}{2}\frac{\partial^2 S}{\partial V^2}dVdV + \frac{1}{2}\frac{\partial^2 S}{\partial \nu^2}d\nu d\nu + \frac{\partial S}{\partial V \partial \nu}dVd\nu \\ &= \frac{\partial S}{\partial V}dV + \frac{\partial S}{\partial \nu}d\nu + (\frac{\partial S}{\partial t} + \frac{1}{2}\frac{\partial^2 S}{\partial V^2}\nu V^2 + \frac{1}{2}\frac{\partial^2 S}{\partial \nu^2}\sigma^2\nu + \frac{\partial S}{\partial V \partial \nu}\sigma\nu\rho)dt. \end{aligned}$$

Hence, there are two randomnesses that affect the movement of the equity price: the firm's asset V and the asset volatility ν. If S and V are both tradable and if we use $\frac{\partial S}{\partial V}$ portion of the firm asset V to hedge the position of S, the risk of $d\nu$ cannot be completely hedged away. Hence, according to ICAPM, if $d\nu$ is related to the change of the future investment opportunities, investors who bear the risk of $d\nu$ require the compensation of this volatility risk, the variance.

Next, consider an option written on the equity of a firm. The price of the option at time t is denoted as O_t. Using Ito's lemma we get

$$\begin{aligned} dO &= \frac{\partial O}{\partial S}dS + \frac{\partial O}{\partial t}dt + \frac{1}{2}\frac{\partial^2 O}{\partial S^2}dSdS \\ &= \frac{\partial O}{\partial S}(\frac{\partial S}{\partial V}dV + \frac{\partial S}{\partial \nu}d\nu) + \mu_o dt \end{aligned}$$

where $\mu_o dt$ is the drift term, and μ_o is expressed by

$$\mu_o = \frac{\partial O}{\partial S}(\frac{\partial S}{\partial t} + \frac{1}{2}\frac{\partial^2 S}{\partial V^2}\nu V^2 + \frac{1}{2}\frac{\partial^2 S}{\partial \nu^2}\sigma^2\nu + \frac{\partial S}{\partial V \partial \nu}\sigma\nu\rho) + \frac{\partial O}{\partial t}]dt + \frac{1}{2}\frac{\partial^2 O}{\partial S^2}((\frac{\partial S}{\partial V})^2\nu V^2 + (\frac{\partial S}{\partial \nu})^2\sigma^2\nu)$$

It can be further derived that

$$E[dO - \frac{\partial O}{\partial S}dS] = 0$$

From the above expression, we observe that the option position can be completely hedged by taking $\frac{\partial O}{\partial S}$ of the underlying equity. The term of $d\nu$ does not show up because the volatility risk of the firm's asset has been take into account in the equity price. By taking the stock position, we hedge the asset risk (dV) and the volatility risk ($d\nu$) of the firm's asset indirectly. Since all the risk sources have been hedged away, there is no compensation demanded by the investors who take the delta-hedged equity option position.

We conclude that the expected return of the delta-hedged equity option position is zero under the capital structure model with stochastic asset volatility. It is not compatible with the empirical evidence that the return of the delta-hedged equity option position is on average negative. Hence, we focus on the capital structure model with jumps in this paper.

Table 1: 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	0.48	0.24	0.16	0.29	0.48	0.64	0.83
Market leverage	0.34	0.25	0.05	0.13	0.29	0.50	0.73
Asset Vol	0.38	0.25	0.16	0.22	0.32	0.47	0.68
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
Idiosyncratic volatility (Idio Vol)	0.38	0.28	0.14	0.20	0.31	0.48	0.71
Realized volatility	0.43	0.29	0.18	0.25	0.36	0.53	0.77
Ex-post VRP	0.003	0.455	-0.191	-0.091	-0.030	0.022	0.171
Vol Deviation	-0.03	2.79	-0.20	-0.04	0.02	0.07	0.17
VTS Slope	-0.02	0.07	-0.08	-0.04	-0.01	0.01	0.03
IV slope	0.01	0.07	-0.03	-0.01	0.01	0.02	0.05
RN skew	-0.69	13.93	-0.82	-0.59	-0.38	-0.18	0.01
RNJump Right	0.25	0.30	0.02	0.06	0.14	0.31	0.60
RNJump Left	0.24	0.27	0.04	0.07	0.15	0.30	0.56

This table reports descriptive statistics of delta-hedged option returns for the pooled data. The data sample period is from January 1996 to August 2014. For call (put) options, delta-hedged return until maturity is calculated as delta-hedged gain scaled by $\Delta S - C$ $(P - \Delta S)$. Moneyness is the stock price over the strike price. Relative bid-ask spread is the difference between bid and ask option price divided by the average of bid and ask price. Implied volatility (IV), delta and vega are provided by OptionMetrics based on the Black-Scholes model. 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 is the logarithm of the firm's market value. Asset volatility is calculated using the methodology in Vassalou and Xing (2004). Idiosyncratic volatility (Idio Vol) is the standard deviation of the residuals of Fama-French three factor model estimated using the daily return over the previous month. Ex-post VRP is the variance risk premium during the life of the option. Vol Deviation is the difference between historical realized volatility and at-the-money implied volatility. The other variables include VTS Slope is the slope of the volatility term structure as in Vasquez (Forthcoming), IV slope is the implied volatility of the smile as in Yan (2011), RN skew is the risk neutral skewness as in Bakshi et al. (2003), and the right-tail and left-tail risk neutral jumps as defined in Bollerslev and Todorov (2011).

Table 2: Time-Series Average of Cross-sectional Correlation

	BL													
ML	0.72	ML												
Asset Vol	-0.29	-0.34	Asset Vol											
Realized Vol	-0.13	-0.13	0.55	Realized Vol										
Implied Vol	-0.17	-0.19	0.66	0.75	Implied Vol									
Idio Vol	-0.15	-0.17	0.57	0.88	0.70	Idio Vol								
Size	0.43	0.61	-0.47	-0.32	-0.44	-0.39	Size							
Ex-post VRP	-0.01	0.00	0.03	0.06	-0.03	0.04	0.00	Ex-post VRP						
Vol deviation	0.09	0.08	-0.35	-0.87	-0.36	-0.74	0.19	-0.13	Vol deviation					
VTS slope	0.02	0.00	-0.20	-0.37	-0.49	-0.30	0.09	0.02	-0.13	VTS slope				
IV slope	0.01	0.00	0.04	0.03	-0.06	0.05	-0.04	0.08	0.09	-0.01	IV slope			
RN skew	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	-0.01	RN skew		
Rnjump right	-0.17	-0.19	0.61	0.73	0.89	0.69	-0.40	0.03	0.39	-0.57	0.00	0.00	Rnjump right	
Rnjump left	-0.16	-0.17	0.60	0.73	0.89	0.67	-0.37	0.04	0.41	-0.59	0.13	-0.01	0.94	Rnjump left

This table presents the Pearson correlation matrix of the variables presented in Table 1 Panel C. Implied volatility (IV), delta and vega are provided by OptionMetrics based on Black-Scholes model. 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 is the logarithm of the firm's asset. Asset volatility is calculated using the methodology in Vassalou and Xing (2004). Idiosyncratic volatility (Idio Vol) is the standard deviation of the residuals of Fama-French three factor model estimated using the daily return over the previous month. Ex-post VRP is the variance risk premium during the life of the option. Vol Deviation is the difference between historical realized volatility and at-the-money implied volatility. The other variables include IV slope (Yan (2011)), RN skewness(Bakshi et al. (2003)) and the right-tail and left-tail risk neutral jumps (Bollerslev and Todorov (2011)).

Table 3: Delta-hedged option return and ex-post variance risk premium

	Cross-section		Time-series	
Intercept	-0.022***	-0.017***	-0.020***	-0.017***
	(-11.76)	(-8.13)	(-48.64)	(-14.66)
ex-post VRP	0.126***	0.126***	0.162***	0.162***
	(21.04)	(21.02)	(49.4)	(49.08)
Gamma		-0.028***		-0.021***
		(-4.05)		(-2.88)
Average adj. R^2	0.210	0.211	0.203	0.206

Note: This table shows the regression results for cross-sectional and time series regression of delta-hedged option return and ex-post variance risk premium. In the cross-section regression, the average number of firms is 990 for each month. In the time-series regression, we select firms with more than 30 observations of delta-hedged option return.

Table 4: Leverage, asset volatility and delta-hedged option return

Panel A: Delta-hedged gain scaled by initial stock price							
Intercept	-0.005	0.000	0.003	Intercept	-0.007	0.000	0.001
	(-5.36)	(-0.39)	-3.56		(-6.91)	(-0.39)	-0.64
ML	0.000		-0.006	BL	0.003		-0.001
	(0.16)		(-4.25)		(2.89)		(-1.50)
Asset Vol		-0.014	-0.017	Asset Vol		-0.014	-0.015
		(-10.40)	(-12.13)			(-10.40	(-10.56)
Adjusted R^2	0.005	0.012	0.018	Adjusted R^2	0.003	0.012	0.014

Panel B: Delta-hedged gain scaled by initial capital							
Intercept	-0.013	-0.002	0.006	Intercept	-0.016	-0.002	0.000
	(-6.41)	(-0.91)	(3.53)		(-7.63)	(-0.91)	-0.23
ML	0.000		-0.013	BL	0.006		-0.003
	(0.10)		(-3.81)		(2.94)		(-1.47)
Asset Vol		-0.03	-0.037	Asset Vol		-0.03	-0.031
		(-10.74)	(-12.38)			(-10.74)	(-10.86)
Adjusted R^2	0.006	0.016	0.023	Adjusted R^2	0.003	0.016	0.017

This table reports the average coefficients (t-statistics) from monthly cross-sectional Fama-MacBeth regressions of delta-hedged call option returns. The sample period covers data from January 1996 through August 2014. Asset volatility is estimated based on Merton model following Vassalou and Xing (2004). ML is market leverage and BL is book leverage. The delta-hedged gain is scaled by initial stock price in Panel A and scaled by initial capital in Panel B. Reported are the coefficients and Fama-MacBeth t-statistics with Newey-West correction for serial correlation.

Table 5: Leverage, asset volatility, and delta-hedged option return with control variables

name	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intercept	0.006	0.010	0.006	0.008	-0.102	0.008	0.011	-0.044
	(3.53)	(5.61)	(3.26)	(4.94)	(-13.69)	(4.32)	(6.18)	(-7.21)
Leverage	-0.013	-0.012	-0.012	-0.013	-0.007	-0.007	-0.010	-0.004
	(-3.81)	(-3.56)	(-3.55)	(-4.33)	(-2.59)	(-2.95)	(-3.07)	(-1.78)
Asset Vol	-0.037	-0.022	-0.033	-0.038	-0.015	-0.037	-0.036	-0.005
	(-12.38)	(-8.86)	(-11.49)	(-13.53)	(-5.83)	(-12.31)	(-12.41)	(-2.41)
Idio vol		-0.468						-0.673
		(-13.34)						(-16.74)
VTS slope			0.093					0.038
			(10.91)					(5.12)
Vol dev				0.015				0.027
				(7.72)				(13.24)
Size					0.007			0.004
					(13.53)			(9.67)
B2M						-0.009		0.000
						(-6.41)		(0.92)
Bid-Ask Spread							-0.038	-0.026
							(-11.27)	(-9.96)
Adjusted R^2	0.023	0.031	0.034	0.029	0.043	0.027	0.039	0.076

This table reports the average coefficients (t-statistics) from monthly cross-sectional Fama-MacBeth regressions of delta-hedged call option returns. The sample period covers data from January 1996 through August 2014. Leverage is the sum of total debt and the par value of the preferred stock, minus deferred taxes and investment tax credit, divided by the firm's market value. Asset volatility is estimated following Vassalou and Xing (2004). Idiosyncratic volatility (Idio vol) is the standard deviation of the residuals of Fama-French three factor model estimated using the daily return over the previous month. Vol deviation is calculated as the difference between realized volatility and implied volatility. VTS slope is the slope of the volatility term structure as in Vasquez (Forthcoming). Size is the logarithm of the firm's market capitalization. B2M is the book to market ratio. Bid-ask Spread is the difference between bid and ask prices divided by the average of the bid and ask prices. Reported are the coefficients and Fama-MacBeth t-statistics with Newey-West correction for serial correlation.

Table 6: Leverage and the delta-hedged option return scaled by asset volatility

name	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intercept	0.007	0.014	0.009	0.011	-0.074	0.010	0.016	0.042
	(1.63)	(2.81)	(2.28)	(2.66)	(-1.67)	(2.26)	(3.45)	(0.67)
Leverage	-0.050	-0.052	-0.049	-0.049	-0.051	-0.041	-0.045	-0.043
	(-2.85)	(-2.95)	(-2.73)	(-2.84)	(-2.98)	(-2.33)	(-2.57)	(-2.46)
Idio Vol		-0.335						-0.863
		(-3.33)						(-3.71)
VTS slope			0.167					0.102
			(5.28)					(3.52)
Vol dev				0.031				0.049
				(4.71)				(5.16)
Size					0.005			0.000
					(1.87)			(0.04)
B2M						-0.013		-0.009
						(-2.90)		(-1.95)
Bid ask spread							-0.067	-0.069
							(-5.13)	(-3.86)
Adjusted R^2	0.008	0.008	0.008	0.008	0.013	0.009	0.010	0.019

This table reports the average coefficients (t-statistics) from monthly cross-sectional Fama-MacBeth regressions of the scaled delta-hedged call option returns. The delta-hedged option return is scaled by the square of asset volatility times 10. The sample period covers data from January 1996 through August 2014. Leverage is the sum of total debt and the par value of the preferred stock, minus deferred taxes and investment tax credit, divided by the firm's market value. Asset volatility is estimated following Vassalou and Xing (2004). Idiosyncratic volatility (Idio vol) is the standard deviation of the residuals of Fama-French three factor model estimated using the daily return over the previous month. Vol deviation is calculated as the difference between realized volatility and implied volatility. VTS slope is the slope of the volatility term structure as in Vasquez (Forthcoming). Size is the logarithm of the firm's market capitalization. B2M is the book to market ratio. Bid-ask Spread is the difference between bid and ask prices divided by the average of the bid and ask prices. Reported are the coefficients and Fama-MacBeth t-statistics with Newey-West correction for serial correlation.

Table 7: Debt maturity and delta-hedged option return return

	(1)	(2)	(3)
Intercept	0.011	0.013	0.013
	(6.38)	(7.13)	(7.22)
Leverage	-0.021	-0.020	-0.020
	(-6.18)	(-6.10)	(-6.13)
Asset Vol	-0.040	-0.041	-0.041
	(-12.43)	(-12.42)	(-12.50)
Short-term debt ratio (CVNT1)	-0.028		-0.011
	(-7.29)		(-2.28)
Long-term debt ratio (CVNT5)		-0.014	-0.012
		(-9.60)	(-7.38)
Adjusted R^2	0.025	0.026	0.026

This table reports the average coefficients (Newey-West t-statistics) from monthly cross-sectional Fama-MacBeth regressions of at-the-money delta-hedged call option returns. Short-term debt ratio (CVNT1) is the ratio of long term debt due in one year divided by total long term debt. Long-term debt ratio (CVNT5) is the ratio of long term debt due within five years divided by total long term debt. The sample period covers data from January 1996 through August 2014.

Table 8: Firm leverage and the cross-section of delta-hedged option returns

(a) Panel A: Market Leverage

	1	2	3	4	5	5-1
Equal weight	-0.0042	-0.0025	-0.0095	-0.0137	-0.0361	-0.0320***
	(-3.63)	(-0.93)	(-3.94)	(-1.93)	(-3.26)	(-3.01)
Open interest weight	-0.0043	-0.0044	-0.0037	-0.0135	-0.0771	-0.0728***
	(-3.64)	(-2.75)	(-0.85)	(-4.41)	(-5.41)	(-5.21)
Value weight	-0.0037	-0.0008	-0.0094	-0.0132	-0.0326	-0.0290**
	(-2.83)	(-0.23)	(-3.42)	(-1.49)	(-2.73)	(-2.50)

(b) Panel B: Book Leverage

	1	2	3	4	5	5-1
Equal weight	-0.0068	-0.0075	-0.0097	-0.0109	-0.0302	-0.0234***
	(-7.06)	(-2.41)	(-2.82)	(-1.39)	(-3.23)	(-2.66)
Open interest weight	-0.0069	-0.0054	-0.0058	-0.026	-0.0577	-0.0508***
	(-6.54)	(-2.61)	(-1.09)	(-2.50)	(-5.07)	(-4.59)
Value weight	-0.0064	-0.0065	-0.0097	-0.0094	-0.0264	-0.0200**
	(-6.33)	(-1.67)	(-2.46)	(-1.00)	(-2.65)	(-2.13)

We scale the delta-hedged option gain by the square of the asset volatility times 10 and report equal-, open-interest-, and value-weighted monthly scaled returns of quintile portfolios formed from the leverage ratio. The last column displays the difference between quintile 5 and quintile 1. In parentheses we report the t-statistics. Panel A displays the results for market leverage and Panel B for book leverage. The sample period for Optionmetrics stocks is January 1996 to August 2014.

Table 9: Return of the long-short leverage portfolio and exposure to the common factors

	1	2	3	4
Alpha	-0.020	-0.040	-0.026	-0.035
	(-2.49)	(-3.98)	(-3.15)	(-2.77)
DHMKT	0.475	0.385	0.564	0.707
	(2.70)	(2.10)	(2.49)	(2.64)
MKTRF	-0.293			-0.100
	(-2.05)			(-0.54)
SMB	0.198			0.222
	(1.01)			(1.12)
HML	-0.221			-0.206
	(-1.20)			(-1.10)
UMD	-0.055			-0.046
	(-0.44)			(-0.36)
$DHMKT^2$		2.624		6.652
		(1.29)		(2.28)
$MKTRF^2$		1.953		1.301
		(2.11)		(0.82)
MKTRF*DHMKT		1.017		6.226
		(0.33)		(1.25)
$DHMKT^3$			-10.537	-38.027
			(-0.83)	(-1.91)
$MKTRF^3$			-2.647	1.037
			(-0.80)	(0.16)
$MKTRF*DHMKT^2$			15.992	28.576
			(1.34)	(1.45)
Adjusted R^2	0.063	0.074	0.076	0.083

This table reports the regression results for different factor models. The dependent variable is the return of the long-short (5-1) portfolio in Table 8. The independent variables are the contemporaneous return of the delta-hedged SP 500 index option divided by the implied variance times 10 ($DHMKT$), the market return ($MKTRF$), the Fama-French and momentum factors (SMB, HML, and UMD). The sample period for Optionmetrics stocks is January 1996 to August 2014.

Table 10: Double sorting on firm characteristics and leverage

Panel A: Double sorting on idiosyncratic volatility and leverage						
	1-ML	2	3	4	5-ML	5-1
1-Idio Vol	0.0005	-0.0060	-0.0162	0.0000	-0.0230	-0.0235**
	(0.16)	(-1.04)	(-2.46)	(0.00)	(-1.92)	(-2.09)
2	-0.0018	-0.0028	-0.0069	-0.0195	-0.0401	-0.0383***
	(-1.07)	(-1.39)	(-2.61)	(-2.92)	(-2.64)	(-2.62)
3	-0.0026	-0.0076	-0.0069	-0.0145	-0.0457	-0.0432***
	(-1.85)	(-2.58)	(-3.90)	(-4.67)	(-3.04)	(-2.95)
4	-0.0044	-0.0048	0.0038	-0.0015	-0.0211	-0.0168
	(-4.58)	(-4.96)	(0.34)	(-0.12)	(-1.42)	(-1.13)
5-Idio Vol	-0.0059	-0.0055	-0.0063	-0.0109	-0.0370	-0.0311***
	(-8.22)	(-6.80)	(-6.79)	(-5.38)	(-3.30)	(-2.83)
Panel B: Double sorting on slope of the volatility term structure and leverage						
	1-ML	2	3	4	5-ML	5-1
1-VTS slope	-0.0057	-0.0065	-0.0037	-0.0224	-0.0789	-0.0732***
	(-5.58)	(-5.15)	(-0.34)	(-6.28)	(-6.18)	(-5.90)
2	-0.0022	-0.0080	-0.0065	-0.0041	-0.0217	-0.0195
	(-1.61)	(-2.50)	(-3.21)	(-0.31)	(-1.08)	(-0.98)
3	-0.0033	-0.0019	-0.0064	0.0023	-0.0331	-0.0298*
	(-2.37)	(-1.02)	(-3.03)	(0.19)	(-2.05)	(-1.89)
4	-0.0004	-0.0012	-0.0106	-0.0130	-0.0259	-0.0256**
	(-0.25)	(-0.65)	(-1.75)	(-1.84)	(-2.33)	(-2.37)
5	-0.0040	-0.0049	-0.0032	-0.0178	-0.0042	-0.0001
	(-3.87)	(-3.89)	(-1.45)	(-2.57)	(-0.29)	(-0.01)
Panel C: Double sorting on volatility deviation and leverage						
	1-ML	2	3	4	5-ML	5-1
1-Vol dev	-0.0062	-0.0079	-0.0104	-0.0315	-0.0703	-0.0641***
	(-3.88)	(-4.12)	(-4.63)	(-4.00)	(-6.93)	(-6.11)
2	-0.0046	-0.0034	-0.0110	-0.0185	-0.0482	-0.0436***
	(-3.85)	(-2.13)	(-2.00)	(-3.12)	(-3.45)	(-3.19)
3	-0.0030	-0.0037	0.0068	-0.0116	-0.0135	-0.0105
	(-2.66)	(-2.12)	(0.59)	(-3.65)	(-0.99)	(-0.78)
4	-0.0021	-0.0056	-0.0063	-0.0032	-0.0114	-0.0093
	(-1.58)	(-2.09)	(-3.16)	(-0.27)	(-0.55)	(-0.46)
5-Vol dev	-0.0023	-0.0016	-0.0029	0.0086	-0.0187	-0.0164
	(-2.13)	(-0.80)	(-1.47)	(0.65)	(-1.35)	(-1.21)
Panel D: Double sorting on size and leverage						
	1-ML	2	3	4	5-ML	5-1
1-Size	-0.0103	-0.0098	-0.0118	-0.0156	-0.0529	-0.0426***
	(-11.78)	(-12.11)	(-12.78)	(-10.97)	(-7.90)	(-6.57)
2	-0.0065	-0.0079	-0.0121	-0.0148	-0.0466	-0.0401***
	(-6.37)	(-7.66)	(-7.87)	(-9.90)	(-9.00)	(-8.27)
3	-0.0051	-0.0071	-0.0109	-0.0154	-0.0284	-0.0233***
	(-4.57)	(-5.37)	(-7.17)	(-7.21)	(-5.79)	(-5.09)
4	0.0001	-0.0035	-0.0064	-0.0100	-0.0198	-0.0199*

	(0.07)	(-2.03)	(-1.55)	(-3.76)	(-1.62)	(-1.66)
5	0.0036	0.0057	0.0127	-0.0063	-0.0205	-0.0241
	(1.06)	(1.87)	(1.34)	(-0.25)	(-0.72)	(-0.85)

This table reports the double sorting results of the average returns of delta-hedged options on firm characteristics and leverage. At the end of each month, the optionable stocks are first sorted into five quintiles based on the the firm characteristic, and then within each quintile, they are further sorted into five quintiles by leverage ratio. Characteristics include idiosyncratic volatility (Cao and Han (2013)), the slope of the volatility term structure (Vasquez (Forthcoming)), the log difference of the realized volatility and implied volatility (Volatility deviation in Goyal and Saretto (2009)), the log of capitalization (Size in Cao et al. (2016)). The t statistics are corrected for serial correlation (Newey-West correction with 2 lags for monthly return). The sample dates from January 1996 to August 2014.

Table 11: Leverage, characteristics and the delta-hedged option return

	1	2	3	4	5	5-1
Idio vol	-0.0024	-0.0053	-0.0071	-0.0091	-0.0335	-0.0311***
	(-1.73)	(-2.59)	(-2.37)	(-1.58)	(-3.76)	(-3.78)
Vts slope	-0.003	-0.0043	-0.0058	-0.0109	-0.0326	-0.0296***
	(-3.18)	(-3.13)	(-1.99)	(-1.97)	(-3.48)	(-3.34)
Vol dev	-0.0037	-0.0044	-0.005	-0.0111	-0.0326	-0.0289***
	(-4.08)	(-3.21)	(-1.76)	(-1.99)	(-3.52)	(-3.28)
Size	-0.0023	-0.0031	-0.0044	-0.0123	-0.0342	-0.0319***
	(-1.54)	(-2.19)	(-1.61)	(-2.08)	(-3.77)	(-3.64)
Bid ask	-0.0045	-0.0053	-0.0051	-0.0111	-0.0312	-0.0266***
	(-5.26)	(-3.99)	(-1.99)	(-1.97)	(-3.35)	(-3.02)

This table reports the average returns of delta-hedged options on stocks of different leverage levels. At the end of each month, the optionable stocks are first sorted into five quintiles based on the the firm characteristic, and then within each quintile, they are further sorted into five quintiles by leverage ratio. The leverage portfolios are averaged over each of the five characteristic portfolios. Characteristics include idiosyncrativ volatility (Idio vol), the slope of the volatility term structure (VTS slope), the log difference of the realized volatility and implied volatility (Vol dev), the log of capitalization (Size), and the bid ask spread (Bid ask).The t statistics are corrected for serial correlation (Newey-West correction with 2 lags for monthly return). The sample dates from January 1996 to August 2014.