Default Risk and Option Returns*

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Abstract

This paper studies the effects of default risk on expected equity option returns. We show that there is a cross-sectional and a time-series relation between default risk and expected option returns. In the cross-section, expected delta-hedged equity option returns have a negative relation with default risk measured by credit ratings or default probability. In the time-series, credit rating downgrades (upgrades) lead to a decrease (increase) in the firm's delta-hedged option return. Our results are consistent with a stylized capital structure model where the negative relation between option returns and default risk is driven by firm leverage and asset volatility.

JEL Classification: C14, G13, G17

Keywords: Delta-Hedged Option Returns, Default Risk, Variance Risk Premium, Volatility, Capital Structure Model

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1 Introduction

The relation between default risk and option prices has been studied extensively. Early research shows that the pricing of ordinary options differs from the pricing of options with default risk (Hull and White, 1995; Jarrow and Turnbull, 1995; Johnson and Stulz, 1987). Recent studies look at the relation between credit spreads and option prices (Andreou, 2015; Carr and Wu, 2011; Cremers, Driessen, and Maenhout, 2008; Culp, Nozawa, and Veronesi, 2018; Geske, Subrahmanyam, and Zhou, 2016)). While all these studies examine option prices, little attention has been paid to the effect of default risk on expected option returns. Meanwhile, there is also limited understanding about the risk-based determinants in the cross section of option returns.[1] In this paper, we study how default risk of the firm drives the cross-sectional dispersion in expected option returns.

We build on the intuition that, the long position of a delta-hedged option portfolio can be considered a hedge against the default risk of the underlying firm, because it provides positive payoffs when the underlying stock experiences large price swings. This makes the delta-hedged option portfolios on the companies with high default risk more attractive to investors seeking to hedge default risk and, therefore, reduces its expected return. When the firm's default risk increases, the expected return of the delta-hedged option portfolio should decrease to reflect the change in default risk.

We motivate this result in a stylized compound option model based on Merton (1974) and Geske, Subrahmanyam, and Zhou (2016). The stock is an option on the firm's asset and an equity option is an option on an option, or a compound option. Expected delta-hedged option returns are proportional to the equity variance risk premium, which in turn depends on the asset variance risk premium and the equity elasticity of the firm's asset. The equity elasticity, or embedded leverage of equity (Frazzini and Pedersen (2012)), increases with the leverage ratio. Firms with higher default risk have higher leverage and higher asset variance, which in turn leads to more negative equity variance risk premium and expected delta-hedged option returns.

We empirically test these implications in the US equity option market from 1996 to 2016.[2] To

[1] See for example Cao and Han (2013), Vasquez (2017), Goyal and Saretto (2009), Zhan, Han, Cao, and Tong (2021).

[2] In a frictionless world, the payoff of a delta-hedged call is identical to the payoff of a delta-hedged put; moreover, their payoffs are also identical to the V-shaped payoff of a straddle. Therefore, to study the returns of put options, call options, or straddles is equivalent as long as they are all delta neutral. In the main analysis of this paper, we present the results for delta-hedged call option returns. The Internet Appendix presents the results for delta-hedged

measure default risk we use credit ratings and default probability. Credit ratings are provided by Standard & Poor's and default probability is calculated as in Bharath and Shumway (2008). We find that options on stocks with high default risk earn significantly lower returns than options on stocks with low default risk. The high minus low return spreads for quintile option portfolios sorted by credit rating and default probability are −0.78% and −0.73% per month with t-statistics of −10.49 and −6.92. The results are robust for call and put options, for straddles, for portfolios that are equal-weighted, weighted by the option open interest and value weighted, and cannot be explained by existing predictors of option returns. We compute the alphas of long-short option portfolios using the Fama and French (2015) five stock factor model, the corporate bond market from Bai, Bali, and Wen (2019), and the delta-hedged call option return of the S&P 500 index. The alphas from these models are negative and significant and of similar magnitude to the average raw option returns.

In the literature, expected equity option returns are related to volatility related variables such as idiosyncratic volatility (Cao and Han (2013)), the difference between long- and short-term implied volatilities (Vasquez (2017)), and the difference between historical and implied volatilities (Goyal and Saretto (2009)). To ensure that volatility related variables does not subsume default risk when predicting option returns, we perform multivariate Fama-MacBeth regressions and double sortings. Fama-MacBeth regressions and double sortings show that default risk predicts option returns above and beyond volatility. We also control for firm characteristics, jump risk, and illiquidity. Firm characteristics include size, return reversal, profitability, return momentum, cash holdings, and analyst forecast dispersion, which have been shown to predict option returns in Zhan, Han, Cao, and Tong (2021). Using Fama-MacBeth regressions and double sorts we confirm that default risk predicts the cross-section of option returns after controlling for these variables.

In addition to the cross-sectional relation of default risk and option returns, we study their time-series relation by exploring the impact of credit rating changes on option returns. We find that credit rating downgrades and upgrades have a statistically significant impact on option returns. For downgrades, option returns decrease after the announcement. The after-minus-before spread, which is the difference between the return after and before the announcement, is negative and statistically significant ranging from −0.5% to −0.6% per month for calls and puts for the window

put option returns. In the paper, we often refer to delta-hedged option returns as option returns, for short.

$[-T; +T]$ where T is equal to 6 and 12 months. For credit rating upgrades, we observe the opposite effect than that for downgrades: option returns increase after an upgrade. Consistent with the model implications, we find that shocks in default risk have a statistically significant impact on delta-hedged option returns.

According to our capital structure model, the drivers of the negative relation between default risk and option returns are leverage and asset volatility. We examine how these variables affect delta-hedged option returns. Consistent with the model implications, Fama-MacBeth regressions show that leverage and asset volatility have negative and significant coefficients. Moreover, the impact of leverage on delta-hedged option returns is more pronounced for high than for low default risk firms.

We also investigate how default risk impacts our understanding of existing anomalies in the cross-section of option returns. Empirical research reports that equity option returns are predicted by firm characteristics such as size, return reversal, profitability, return momentum, cash holdings, analyst forecast dispersion (all by Zhan, Han, Cao, and Tong (2021)), deviation between realized and implied volatility (Goyal and Saretto (2009)), the slope of the volatility term structure (Vasquez (2017)), idiosyncratic volatility (Cao and Han (2013)), and the bid-ask option spread (Christoffersen, Goyenko, Jacobs, and Karoui (2017)). We study the long-short return spread for each option anomaly and find that in nine out of ten cases the return spread (in absolute value) increases with the level of default risk. Moreover, five anomalies—size, lagged twelve-month return, cash-to-asset ratio, profitability, and analyst earnings forecast dispersion—are only profitable for high default risk firms. Our results show that the predictability of existing anomalies in the equity option market is concentrated on high default risk firms. Default risk may potentially provide a risk-based explanation to partially understand other anomalies. The results are similar in spirit to those in Vassalou and Xing (2004) and Avramov, Chordia, Jostova, and Philipov (2013), who study the relation between default risk and other anomalies in the stock market.

Our paper contributes to the literature in two ways. First, we contribute to the literature on the role of default risk on the pricing of contingent claims of the underlying firm. We are the first to document a cross-sectional and time-series relation between default risk and expected delta-hedged option returns. Several related papers study the link between default risk and equity option prices such as (Carr and Wu (2011), Geske, Subrahmanyam, and Zhou (2016), and Culp, Nozawa, and

Veronesi (2018). However, we are the first to study the impact of default risk on delta-hedged option returns which reflect the equity variance risk premium.

Second, we explore one economic channel, default risk of the firm, that differentiates the pricing of delta-hedged option returns. While the predictability of equity option returns reported in the previous studies is mostly explained by market inefficiencies or investors' behavioral biases, our study provides a risk-return channel to understand the determinants of expected equity option returns. We show that delta-hedged option buyers are willing to pay a higher premium for high default risk firms, potentially to hedge away higher volatility risk.

We recognize several limitations in this paper. First, it is not entirely possible to disentangle the role of volatility risk and default risk because the two risks typically comove with each other. To address this issue, we argue that credit rating announcements produce a shock to credit risk of the underlying firm rather than a shock to volatility risk; hence, it is more likely that default risk drives volatility risk than the other way around. Second, our model assumes one representative firm, so only time-series implications can be derived. To generate cross-sectional implications, we require heterogenous firms in the model, which we leave for future research.

The remainder of the paper is organized as follows. In Section 2, after presenting the capital structure model, we derive the relation between option returns and default risk and explore the drivers of this relation. Section 3 describes the data and reports summary statistics. Section 4 reports the cross-sectional and time-series results. Section 5 concludes the paper.

2 The Model

To study the relation between default risk and option returns, we consider a stylized capital structure model with jumps. Our model is a compound option model similar to the one in Chen and Kou (2009), which is an extension of the capital structure model by Merton (1974) and Geske, Subrahmanyam, and Zhou (2016). The model in Geske, Subrahmanyam, and Zhou (2016) contains two option layers: the equity option is an option on the stock, and the stock is an option on the firm's assets. They model the firm's assets with a geometric Brownian motion with constant volatility.

To generate non-zero expected delta-hedged option returns, as found in empirical studies such as Bakshi and Kapadia (2003b), Goyal and Saretto (2009) and Cao and Han (2013), we extend the model in Geske, Subrahmanyam, and Zhou (2016) by including jumps to the asset process. A model with jumps captures the stylized fact that bankruptcy normally occurs after a large drop in the firm value, while providing a closed form solution of equity values in compound option models.[3]

2.1 The Process of the Firm Asset and Equity

We first specify 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. J_i is the jump size, where $J_1, J_2, ..., J_n$ are independently and identically distributed with a probability density function $f(.)$. The specification of jump occurrence and jump size is standard in the literature (Kou (2002), Cremers, Driessen, and Maenhout (2008), Todorov (2010), and Christoffersen, Jacobs, and Ornthanalai (2012)). We further assume that the jump risks related to the jump intensity λ and the jump size J_i are priced. Hence, after a change of measure (see details in Internet Appendix IA.2), the asset value V_t has the following process under the risk neutral measure

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

where λ^Q and $E^Q(J_i)$ represent jump intensity and the expected jump size of the asset return under the risk neutral measure.

The firm issues two classes of claims: equity and debt. On calendar date T, the firm promises to pay a total of D dollars to bondholders. In the event this payment is not met, bondholders immediately take over the company and shareholders receive nothing. The debt does not pay

[3] Including stochastic volatility can also generate non-zero expected delta-hedged option returns. The process of the firm's asset value with stochastic volatility under the physical measure is $\frac{dV_t}{V_t} = \mu dt + \sqrt{\nu_t} dW_{1t}, d\nu_t = \theta_t dt + \sigma\sqrt{\nu_t} dW_{2t}$. The volatility of the asset return, ν_t, is driven by a diffusion process dW_{2t} that is correlated with dW_{1t} with constant correlation coefficient ρ. The expected delta-hedged gain is equal to $E[\Pi_{0,t}] = E[\int_0^t \frac{\partial O_t}{\partial(\sigma_S)^2} \frac{\partial(\sigma_S)^2}{\partial \nu_t} \lambda(\nu_t) dt]$ where $(\sigma_S)^2$ is the variance of equity return and $\lambda(\nu_t) = cov(\frac{dm_t}{m_t}, d\nu_t)$ is the asset variance risk premium for a pricing kernel m_t. A stochastic volatility model does not provide equity values in closed form.

coupons nor has embedded options. We assume that default is triggered at any time before maturity. In addition, the firm cannot issue any new senior claim on the firm, nor can it pay cash dividends, nor can it do share repurchases prior to the maturity of the debt.

The value of the equity is a call option on the firm's assets V_t with strike D and 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, we use Ito's formula to obtain the process of the equity value:

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

where $\sigma_{S_t} = \frac{\partial S_t}{\partial V_t}\frac{V_t}{S_t}\sigma$, and $\mu_S^Q = r - \frac{\lambda^Q}{S_t}E^Q[S(V) - S(V-)]$ since the discounted equity price process is a martingale under the risk neutral measure. This stylized capital structure model captures the leverage effect through the expression of the stock volatility $\sigma_{S_t} = \frac{\partial S_t}{\partial V_t}\frac{V_t}{S_t}\sigma$. When the stock price decreases, the market leverage of the firm $\frac{D}{S_t}$ and the stock volatility σ_{S_t} increase, which in turn produces the contemporaneous negative relation between stock returns and stock volatility.[4]

2.2 Delta-hedged Option Gains on Levered Equity

We now turn to the valuation of options written on the levered equity and the computation of the expected gain of a delta-hedged option portfolio. In this sub-section we work with delta-hedged option gains since they are simpler to derive. In the paper we work with delta-hedged option returns that are equal to the delta-hedged option gain scaled by the absolute value of the initial investment. Hence, delta-hedged option gains and returns share the same sign but option returns are directly comparable across firms.

The value of an European option $O(0, t; K)$ on equity $S(V)$ at time 0, maturing at t, with strike price K is equal to $e^{-rt}E^Q[\max(S_t(V_t) - K, 0)]$ for calls and $e^{-rt}E^Q[\max(K - S_t(V_t), 0)]$ for puts. We work with delta-hedged options so that the option return reflects the variance risk premium since it is immune to changes in the underlying stock price. The delta-hedged gain is the gain of a long position in an option hedged by a short position in the underlying stock net of the risk-free rate earned by the portfolio and is defined as $\Pi_{0,t} = O_t - O_0 - \int_0^t \Delta_u dS_u - \int_0^t r(O_u - \Delta_u S_u)du$

[4]Note that the stock volatility σ_{S_t} changes over time but is not stochastic. σ_{S_t} carries no risk premium and can be completely hedged away.

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.

The following proposition shows the expression of the expected delta-hedged gain in terms of the option gamma, the equity elasticity, the asset variance, and the stock price. Details of the derivation are provided in the Internet Appendix IA.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 (3). The expected delta-hedged gain is equal to*

$$E(\Pi_t) \approx E[\int_0^t \frac{1}{2} \frac{\partial^2 O_u}{\partial S_u^2} \epsilon_S^2 \left((\sigma_v^P)^2 - (\sigma_v^Q)^2\right) S_u^2 du] \tag{4}$$

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

From Proposition 1, the expected delta-hedged option gain is a function of the option gamma, the square of the equity elasticity, the asset variance risk premium, and the square of the stock price.

The sign of the expected delta-hedged option gain is determined by the sign of the asset variance risk premium. We know that the equity variance risk premium is equal to $EVRP = \epsilon_S^2 AVRP$ where $AVRP$ is the asset variance risk premium equal to $(\sigma_v^P)^2 - (\sigma_v^Q)^2$ and ϵ_S is the equity elasticity.[5] Financial literature documents that the sign of the equity variance risk premium is negative for the cross-section of equity options (Bakshi and Kapadia (2003b), Goyal and Saretto (2009), and Cao and Han (2013)) and for the S&P 500 (Bakshi and Kapadia (2003a) and Carr and Wu (2009)). Therefore we assume that the sign of the asset variance risk premium and the expected delta-hedged option gain is negative.

Asset variance risk premium is not zero even though our model does not have stochastic volatility. The asset (and equity) volatility under the physical measure differs from the volatility under the risk neutral measure because jump risk is priced in the economy. The asset variance risk premium

[5] The variance risk premium in the empirical part of this paper is the equity variance risk premium, unless otherwise noted.

is equal to $\lambda E[J-1]^2 - \lambda^Q E^Q[J-1]^2$. Assuming that the jump intensity is priced, that jump size is not priced, and that $\lambda^Q = \lambda\phi$, we obtain $AVRP = \lambda E[J-1]^2(1-\phi)$. Since the price of risk is negative ($\phi > 1$), as the jump variance risk in the physical measure $\lambda E[J-1]^2$ increases, the asset variance risk premium decreases. The jump variance risk increases when the jump intensity or the jump size increases.

Finally, delta-hedged option gains and the equity variance risk premium depend on firm leverage and asset volatility. Equity elasticity is increasing in firm's leverage ratio $\frac{D}{V_t}$. As the firm's leverage changes over time, so does the equity volatility. As the firm leverage increases, the equity volatility risk premium and the expected delta-hedged gains become more negative. Asset volatility changes over time due to unanticipated jumps in the asset process. As the price of jump risk associated with the jump intensity and the jump size increases, the asset variance risk premium decreases. Finally, as the asset volatility increases, asset variance risk premium, equity variance risk premium, and option returns become more negative. Both jumps and stochastic volatility can be sources of variance risk of the firm's asset. To distinguish the main source of asset variance risk premium requires high-frequency data of the firm's asset price that is not currently available.

2.3 Relation between Default Risk and Option Returns under the Capital Structure Model

We derive the relations between delta-hedged option returns and structural firm characteristics using the compound option pricing model with jumps. To derive these relations requires analytical expressions of the delta-hedged option return, default probability, gamma, and equity elasticity as per Proposition 1. Since analytical expressions of some of these variables are not available in our model, we use numerical simulations of our jump-diffusion model to derive the relation between default risk and expected delta-hedged option returns. Details of the jump distribution, pricing kernel, measure transformation, valuation of the firm's equity, and default probability are provided in the Internet Appendix IA.2; details of the numerical simulation and the parameters used in it are reported in the Internet Appendix IA.3.

Figure A.1 reports the results from the numerical simulations. Figures 1(a), 1(b), and 1(c) plot delta-hedged call option returns against default probability for three leverage ratios: 0.2, 0.4, and 0.6. Delta-hedged option returns are defined as the delta-hedged option gain scaled by the absolute value of the initial investment of the portfolio. In all three figures, the jump intensity varies between 0.1 and 1. We observe that as default probability increases, option returns decrease for the three levels of leverage. Note that as leverage increases, default probability takes higher values and delta-hedged option returns are more negative. These figures show a negative relation between default risk and delta-hedged option returns. We formulate the following hypothesis that we empirically confirm in the paper.

Hypothesis 1 *For a negative price of volatility risk* ($1-\phi<0$)*, the expected delta-hedged return* $\frac{E(\Pi_t)}{|O_0-\Delta_0 S_0|}$ *is decreasing in default probability.*

Higher default risk is associated with higher levels of leverage, asset volatility, and jump intensity. Given a common negative shock to the asset value of the firm, stocks with higher default risk will experience larger downside movements of the stock return, which leads to drastic increases in the stock return volatility due to the leverage effect. Buyers (sellers) of delta-hedged options get a positive (negative) payoff when the stock has a large return or when the stock volatility drastically increases. Consequently, buyers are willing to pay a premium to hedge against potential increases in volatility or negative jumps in returns, while sellers require compensation for bearing the volatility risk. Hence, the return on the delta-hedged option reflects the variance premium, which is negative on average and more negative for higher default risk firms. This is not contradictory to the common belief that high risk is associated with high return. When investment opportunities deteriorate, stocks perform worse while delta-hedged options perform better since they hedge against higher volatility risk.

Figure A.2 plots delta-hedged option returns for different levels of leverage and asset volatility. As leverage or asset volatility increases, option returns decrease as reported in Figure A.2. Overall, delta-hedged option returns are negatively related with default risk. That relation is driven by leverage and asset volatility.

The following hypothesis summarizes the discussion of the relation between expected delta-hedged returns with asset volatility and leverage.

Hypothesis 2 *For a negative price of volatility risk, the expected delta-hedged return is more negative for firms with higher asset volatility and higher leverage.*

We test these two hypotheses using equity option data from the US equity option market. The empirical evidence supports these hypotheses as shown in Section 4.

3 Data

3.1 Option data and delta-hedged option returns

The data on equity options are from the OptionMetrics Ivy DB database. The dataset contains information on the entire US equity option market from January 1996 to April 2016. 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, Ross, and Rubinstein (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. The reason is that financial firms usually have much higher leverage than other firms. The high leverage is normal for these firms, but it does not have the same meaning for non-financial firms, where high leverage more likely indicates distress.

In this paper we use at-the-money (ATM) options, either calls or puts, instead of out-of-the-money (OTM) puts. While out-of-the-money puts are better suited when studying option prices and their relation with default risk, at-the-money options are preferred when working with delta-hedged option returns. OTM put options provide information on the left tail of the distribution of the underlying stock while ATM options have the highest Vega across all strikes which is ideal to capture the volatility risk premium embedded in delta-hedged option returns (Bakshi and Kapadia (2003a)).

At the end of each month and for each optionable stock, we get the call and put options closest to at-the-money and with the shortest maturity among those with more than one month to expiration. We apply the following filters. First, to avoid the early exercise premium of American options, we exclude options whose underlying stocks pay dividends during the remaining life of the option. Second, prices that violate arbitrage bounds are eliminated. Third, an observation 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 options trading below 3 and 0.10 otherwise), or (iv) there is no open interest for that option.

We compute delta-hedged option returns which are equal to the delta-hedged option gain $\Pi_{t,t+\tau}$ scaled by the absolute value of the initial investment, i.e. $|\Delta_t S_t - O_t|$ for call and put options, following Cao and Han (2013) and Zhan, Han, Cao, and Tong (2021). We work with delta-hedged option returns since they are directly comparable across stocks and share the same sign with delta-hedged gains.

Delta-hedged option gains hold a long position in an option, hedged by a short position of delta shares on the underlying stock. The option is hedged discretely N times over the period $[t, t+\tau]$, where the hedge is rebalanced at each date t_n, $n = 0, 1, ..., N-1$. The discrete delta-hedged option gains up to time $t+\tau$ is defined as,

$$\Pi_{t,t+\tau} = O_{t+\tau} - O_t - \sum_{n=0}^{N-1} \Delta_{t_n}[S_{t_{n+1}} - S_{t_n}] - \sum_{n=0}^{N-1} \frac{a_n r_{t_n}}{365}(O_{t_n} - \Delta_{t_n} S_{t_n}), \quad (5)$$

where O_t is the price of the option, Δ_{t_n} is the delta of the option at time t_n, r_{t_n} is the annualized risk-free rate, and a_n is the number of calendar days between t_n and t_{n+1}. We compute delta-hedged gains for call and put options using this definition and the corresponding option price and delta.[6] We work with monthly delta-hedged option returns. The position is opened at the end of the month and closed at the end of the following month.

3.2 Variables related to default risk

We use two measures to approximate the default risk of a firm. The first measure is credit ratings provided by Standard & Poor's, which is obtained from Compustat on WRDS. Standard & Poor's rating definitions specify S&P's issuer credit rating as a current opinion of an obligor's overall financial capacity (creditworthiness) to pay its financial obligations. This opinion focuses on the obligor's capacity and willingness to meet its financial commitments as they come due. In the empirical analysis, we transform the S&P ratings into numerical scores where 1 represents a AAA rating and 22 reflects a D rating. Hence, a higher numerical score reflects higher default risk. Numerical ratings of 10 or below (BBB- or better) are considered investment-grade, and ratings of 11 or higher (BB+ or worse) are labeled high-yield or non-investment grade.

[6] 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 second measure to approximate default risk is the default probability calculated using a structural KMV-Merton type model. We closely follow the procedure in Bharath and Shumway (2008) with the iterated estimate of the volatility of the firm value to get estimates of default probability. Default probability is equal to $N(-\frac{\ln(V/D)+(\mu-0.5\sigma_v^2)T}{\sigma_v\sqrt{T}})$, where N(.) is the cumulative normal distribution, V is the total value of the firm, D is the face value of the firm's debt, μ is an estimate of the expected annual return of the firm's assets that is calculated using historical returns of the firm's asset, and σ_v is the volatility of the firm value. V and σ_v are solved numerically from the following two equations: $S = VN(d_1) - e^{-rT}FN(d_2)$ and $\sigma_S = (V/S)N(d_1)\sigma_V$, where S is the market value of the firm's equity, σ_S is the volatility of the firm's equity, $d_1 = \frac{\ln(V/D)+(r+0.5\sigma_v^2)T}{\sigma_v\sqrt{T}}$ and $d_2 = d_1 - \sigma_v\sqrt{T}$. With this procedure we compute asset volatility and default probability for each firm.[7] The estimation requires data of debt in current liabilities (Compustat item 45), total long-term debt (Compustat item 51), and daily stock price that we get from CRSP. Appendix A.1 contains a detailed definition of the variables used in the paper.

3.3 Other variables

We include variables that predict the cross-section of option returns such as size, stock reversal ($RET_{(-1,0)}$), stock momentum ($RET_{(-12,-1)}$), cash-to-asset ratio, profitability and analyst dispersion as in Zhan, Han, Cao, and Tong (2021), idiosyncratic volatility as in Cao and Han (2013), volatility risk premium as in Goyal and Saretto (2009), the slope of volatility term structure as in Vasquez (2017), and the illiquidity measure as in Christoffersen, Goyenko, Jacobs, and Karoui (2017).

Size is defined as the natural logarithm of the market value of the firm's equity (Banz (1981) and Fama and French (1992)). The stock return reversal is the lagged one-month return (Jegadeesh (1990)). Stock return momentum is the cumulative return on the stock over the eleven months ending at the beginning of the previous month (Jegadeesh and Titman (1993)). Cash-to-assets ratio is the value of corporate cash holdings over the value of the firm's total assets (Palazzo (2012)). Profitability is earnings divided by book equity in which earnings are defined as income before extraordinary items (Fama and French (2006)). Analyst earnings forecast dispersion is

[7]We use the SAS code provided by Tyler Shumway: http://www-personal.umich.edu/~shumway/papers.dir/nuiter99_print.sas.

the standard deviation of annual earnings-per-share forecasts scaled by the absolute value of the average outstanding forecast (Diether, Malloy, and Scherbina (2002)). Idiosyncratic volatility is the standard deviation of the residuals of the Fama-French three-factor model estimated using daily stock returns over the previous month (Ang, Hodrick, Xing, and Zhang (2006)). Volatility risk premium is the difference between historical volatility over the previous year and the Black-Scholes implied volatility for at-the-money options (Goyal and Saretto (2009)). The slope of the volatility term structure is the difference between long-term and short-term implied volatilities (Vasquez (2017)). Bid-ask spread is defined as $2(O_{ask} - O_{bid})/(O_{bid} + O_{ask})$, where O_{bid} is the highest closing bid option price and O_{ask} is the lowest closing ask option price. Christoffersen, Goyenko, Jacobs, and Karoui (2017) document that equity options with higher illiquidity earn a higher return in the future. Since we do not have intraday option data as in Christoffersen, Goyenko, Jacobs, and Karoui (2017), we use relative bid-ask spread to measure illiquidity in the equity option market.

We also construct variables related to the capital structure of the firm using balance sheet data from Compustat. Leverage is computed 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 equity.[8] The definition of all variables is reported in Appendix A1.

3.4 Summary statistics

Table 1 presents summary statistics for call and put delta-hedged option returns in Panels A and B. Delta-hedged option returns for call and put options are negative on average at −0.75% and −0.49%. The average moneyness of the options is close to one and the maturity is about 47 days. The implied volatility is on average 47% for calls and 49% for puts.

Panel C reports summary statistics of firm characteristics including credit rating, default probability, idiosyncratic volatility, the slope of the volatility term structure, volatility risk premium, size, and bid-ask spread. Asset volatility is on average smaller than realized equity volatility, confirming the findings in Choi and Richardson (2016).

Table 2 reports the correlations of firm characteristics. As expected, there is a high positive

[8] Our results remain unchanged if we use book leverage. To compute book leverage the denominator is book equity instead of market equity.

correlation of 43% between credit rating and the logarithm of default probability. Both credit rating and default probability are positively correlated with market leverage and asset volatility. Market leverage is negatively correlated with all volatility related variables and reports the lowest correlation with asset volatility at −39%. This is consistent with the endogenous leverage model where the agent chooses the optimal capital structure according to the asset volatility of the firm. Existing option return predictors such as volatility risk premium and the slope of the volatility term structure have low correlation with default probability at −8% and 3%. Idiosyncratic volatility has a positive correlation with credit rating (47%) and default probability (20%). In the next section, we empirically test the relation between default risk measures and future option returns.

4 Cross Sectional Analysis

In this section we present empirical evidence that default risk is related to future delta-hedged option returns. Using portfolio sorts and Fama-MacBeth regressions, we document the relation between credit ratings and default probability with future option returns. We report the risk-adjusted option returns using stock return factors as well as option market factors. In Fama-MacBeth regressions and double sorts, we control for existing option return predictors. Finally, we analyze the impact of credit rating upgrades and downgrades on option returns.

4.1 Option Returns sorted on Default Risk

We study how delta-hedged option returns are related to default risk using portfolio sorts. We define delta-hedged option return as the delta-hedged gain scaled by the absolute value of the initial investment to be consistent with existing studies such as Goyal and Saretto (2009) and Cao and Han (2013). We find that there is a negative relation between default risk and option return of delta-hedged calls and puts.

Table 3 presents delta-hedged call option returns for quintile portfolios sorted by two default risk measures: credit rating in Panel A and default probability in Panel B.[9] Each month we rank options by the default risk measure into quintiles and construct equal-, option open-interest, and value-weighted portfolios.

[9]The results remain unchanged if we exclude firms rated C and below. Grouping by rating categories makes the long-short returns more negative.

Panel A reports the results for portfolios sorted on credit rating. Credit rating increases from 4.53 (or A+ S&P rating) for quintile 1 to 13.83 (or B+ S&P rating) for quintile 5. While default risk increases from quintile 1 to quintile 5, option returns monotonically decrease. The raw return of quintile 1 is -0.18% while that of quintile 5 is -0.97%. The long-short call option return is -0.78% with a t-statistic of -10.49. The results are similar for value-weighted and option open-interest weighted portfolios where the spread between quintiles 5 and 1 is -0.79% with a t-statistic of -6.99.

In Panel B of Table 3, we repeat the exercise for an alternative measure of default risk: default probability. An advantage of default probability over credit rating is that default probability changes with updates to the balance sheet information. Hence, default probability of a firm can change while its credit rating stays the same. Moreover, a firm might experience large changes in its default probability prior to a credit rating change.

Panel B reports equal-, option open-interest, and value- weighted call option returns for portfolios sorted on default probability. While portfolio 1, the one with the lowest default probability of 7.45×10^{-7}, reports the highest option returns, portfolio 5, with a default probability of 16%, reports the lowest returns. The long-short equal-weighted option portfolio has a return of -0.73% with a t-statistic of -6.92. The average option returns are negative for all five portfolios for equal-, option open-interest and value weighted portfolios. Finally, the option open-interest and the value-weighted spread, which is the difference between quintiles 5 and 1, are also negative and significant.

In Table IA1, we confirm the negative relation between default risk and an alternative definition of option returns. We use delta-hedged puts instead of calls. Since option returns are delta-hedged, the payoffs of both strategies are identical: the V-Shaped–like payoff of a straddle. Table IA1 confirms that default risk predicts delta-hedged returns for put options. When sorting by credit risk and default probability, the long-short delta-hedged put option return is negative and statistically significant for equal- and option open-interest weighted portfolios. Next, we use straddle returns and confirm the negative relation between option returns and default risk. In the first column of Table 9 Panel B, "No cost", the relation is positive since we are shorting, not buying, straddles to analyze the profitability of the strategy. This result is consistent with a negative relation between option returns and default risk. We also create five credit rating groups where 3 are investment grade and two are non investment grade. The results are robust to this alternative groupings and are reported in Table IA3.

Overall, we find that future option returns are negatively related with two measures of default risk. The results hold for various option return definitions and the long-short option returns in all specifications are negative and statistically significant.

In our stylized model, what drives the variance risk premium is the jump part of variance, not the diffusion part. The negative jumps in stock returns normally occur during economic downturns. We would expect our main results to be stronger during economic downturns and when the market returns are negative. In Table IA10 in the internet appendix of the paper, we show supportive evidence in several subsamples. This table reports quintile delta-hedged call option portfolio returns sorted on credit rating for different subsamples: crisis and no crisis, negative market return and positive market return, high and low liquidity. The crisis and no-crisis periods are classified based on the recession and expansion indicators from The National Bureau of Economic Research (NBER). The negative and positive market return periods are based on months in which S&P 500 returns are negative or positive. Periods of high and low liquidity are determined according to the Amihud (2002) liquidity measure computed for the S&P 500. Portfolios are weighted equally (EW), with the option's open interest (OW), and with the capitalization of the underlying stock (VW).

The results show that the long-short returns are stronger in magnitude during recessions, when the market returns are negative, and when the market liquidity is low. This is consistent with the intuition that the results are related to systemic risk and economic downturns. When the jump intensity in the market return becomes higher, given a certain exposure of the firm's asset return to the market return, the delta-hedged gain becomes more negative. Meanwhile, we would not expect the result to exist only in economic downturn periods. If the market jump intensity is not equal to zero, jump intensity contributes to the market variance risk premium. Hence, we expect the result to hold during normal times. Corporate defaults normally realize and cluster in recessions, but during normal times when default probability is not equal to zero, there is still a default risk premium.

To further understand the relation between default risk and delta-hedged option returns sorted by credit rating, we plot the total number of defaults per year against the average long-short option return per year. The option return per year is the average of the monthly long-short delta-hedged option returns. The number of defaults per year corresponds to the number of firms with a 'D' credit rating. According to S&P Global Ratings Definitions, "an obligation rated 'D' is in payment default. The 'D' rating also will be used upon the filing of a bankruptcy petition or the taking of a similar action if payments on an obligation are jeopardized." Figure A.3 plots the number of defaults per year against the long-short delta-hedged call option returns. Two facts emerge from the plot. First, there is a negative relation between the number of defaults and long-short option returns. Second, the greatest number of defaults occur during the dot-com crisis and the 2008-2009 financial crisis. The years 1999 to 2003 and the year 2009 experience the highest number of defaults during our sample. In addition, the most negative long-short option returns also occur during the two crises: 1999, 2000, 2002, and 2009. These results show that during economic downturns, and more specifically during high defaults periods, long-short option returns are highly negative.

4.2 Factor Exposures of the Long-Short Returns

In the previous subsection, we report a strong negative relation between default risk and option returns. One implication of our model is that the relation between default risk and option returns is potentially driven by systematic factors. To examine whether the long-short return is exposed to traditional asset pricing factors, we regress the long-short option spread, which is the difference between quintiles 5 and 1, on a set of market-wide risk factors. Since no pricing model is available for equity option returns, we use factors in the stock market, the corporate bond market, and the equity option market.

The first model we use is the Fama and French (2015) five stock factor model. This model includes the market factor (MKT), the size effect (SMB), the value effect (HML), the investment factor (CMA), and the profitability factor (RMW). In the second model we add four common factors in the corporate bond market proposed by Bai, Bali, and Wen (2019). The factors are the value-weighted corporate bond market excess return (MKT_Bond), the downside risk factor (DRF), the credit risk factor (CRF), and the liquidity risk factor (LRF). In the third model, we add the delta-hedged call option return of the S&P 500 index (DH_SP500).

Table 4 reports the alphas of the long-short call option portfolios along with the betas of the factor regressions. The first model uses the five factors of the Fama-French model. The alpha of the long-short trading strategy that sorts on credit rating is negative and significant. The alpha is

-1.07% with a t-statistic of -6.65. Model 2 adds the four factors proposed by Bai, Bali, and Wen (2019). The alpha remains negative and significant. Model 3 adds the S&P 500 delta-hedged call option return as an additional factor. The alpha is -1.17% with a t-statistic of -7.16. Some of the loading are significant for these models. While the loadings of the corporate bond market excess return, the liquidity risk factor, the S&P 500 delta-hedged call option returns, and the market default spread factor are positive and significant, the beta of the downside risk factor is negative and significant.

We perform the analysis on the long-short portfolios sorted by default probability. The results are qualitatively similar. The long-short option portfolio returns have a negative loading on the market risk factor, and a positive loading on HML and the credit risk factor. The positive loading of option returns on the delta-hedged option return of the S&P 500 is expected: the long-short option portfolio is positively related to the delta-hedged option return of the market. Another interesting result is the negative relation of the long-short option portfolio with the market risk factor and with the downside risk factor, which is the second lowest monthly return over the last 36 months. This negative relation indicates that the long-short option portfolio is a hedge on market downturns; it is a strategy that makes money when the market quality worsens. Overall, we find that the alphas of the long-short portfolios are negative and significant. We also show that, in most models, the long-short portfolio has a positive exposure to the delta-hedged option return of the S&P 500 index and a negative exposure to the market and the downside risk factors.

To clarify the point that in the stylized model in this paper the relation between default risk and option returns is driven by firms' heterogeneous exposure to the systematic risk, we examine the betas of quintile portfolios to systematic risk factors in Table IA11. This table reports in Panel A (Panel B) the alphas and betas of time-series regressions of equal-weighted quintile call option portfolio returns (variance risk premia) sorted by credit rating. The factor model includes delta-hedged option returns (variance risk premia) of the S&P 500 and credit spread in Panel A (Panel B). The table shows that the high-low return has significant exposure to the delta-hedged option return on the stock index. The betas of the market delta-hedged return monotonically increase from quintile 1 to quintile 5, which is consistent with our stylized model. The alpha remains significant, suggesting that the delta-hedged option return on the index cannot fully explain the long-short return. The reason might be due to the time-varying nature and measurement error in betas and in the market factor. In the spirit of Fama and French (1993) and Kelly, Pruitt, and Su (2019), we argue that the relationship between some characteristics and option returns is driven by compensation for exposure to latent risk factors. Due to the measurement errors in the exposure to latent risk factors, characteristics might be better measures for the exposure to latent risk factors. We also argue that default risk is one of the characteristics that help us understand the risk and return relationship in the equity option market.

4.3 Fama-MacBeth Regressions

To study whether the negative relation between default risk and future option returns can be explained by other related variables, we run Fama-MacBeth cross-sectional regressions. The literature documents several firm characteristics that predict future equity option returns. These characteristics are size, return reversal, profitability, return momentum, cash holdings, analyst forecasts (all by Zhan, Han, Cao, and Tong (2021)), idiosyncratic volatility (Cao and Han (2013)), volatility risk premium (Goyal and Saretto (2009)), the slope of the volatility term structure (Vasquez (2017)), and the bid-ask option spread (Christoffersen, Goyenko, Jacobs, and Karoui (2017)). We control for these variables in the bivariate Fama-MacBeth regressions in Table 5.

In the literature, several studies (Bali, Cakici, and Whitelaw, 2011; Campbell, Hilscher, and Szilagyi, 2008; Conrad, Kapadia, and Xing, 2014) show that firms which are likely to default also tend to have extreme positive stock returns, suggesting that the impact of default risk on expected stock returns could be due to stocks' lottery characteristics. To investigate the lottery demand explanation, we include two measures to investigate if investors demand for lottery-like options can be a potential explanation of the distress risk premium in the equity option market. The measures include the maximum daily return in a month (MAX (1)) and the average of the five highest daily returns in a month (MAX (5)). Other studies (An, Ang, Bali, and Cakici, 2014; Boyer and Vorkink, 2014; Cremers and Weinbaum, 2010; Xing, Zhang, and Zhao, 2010) show that skewness-related measures have significant relation with equity option returns and stock returns. We include risk-neutral skewness, measured by the spread between out-of-the-money put implied volatility and the average of at-the-money call and put implied volatilities with 30 days to maturity, to control for skewness.

Table 5 reports the time-series average of the regression coefficients for delta-hedged call options for two measures of default risk.[10] We measure default risk with credit rating and default probability. The first row reports a univariate regression of delta-hedged options on default risk and the remaining rows report bivariate regressions that include one control variable at a time. Column 2 to Column 5 in Table 5 reports regression results for credit rating. The regressions confirm the negative relation between credit rating and delta hedged call options. The coefficient of credit rating is negative and highly significant in both cases. Next we include one control variable at a time. In all regressions, the coefficient of credit rating is negative and statistically significant. For example, the regression that includes credit rating and idiosyncratic volatility for call options reports a negative and significant coefficient for both variables. In this case, the coefficients for credit rating and idiosyncratic volatility are -0.001 and -0.011 with corresponding Newey-West t-statistics of -8.39 and -5.57. This result also shows that default risk predicts option returns beyond idiosyncratic volatility.

In addition, we find the coefficient of MAX (1) is negative and significant when credit rating or default probability are included in the regression. The coefficient of MAX (5) is negative and significant when default probability is included in the regression. It shows that the higher the lottery demand of the underlying stock, the lower the future option return. It is consistent with the explanation that the lottery demand of the underlying stock spills over to the option market, pushing the option price up and lowering future option returns. The coefficients of both credit rating and default probability remain significant after controlling for the two lottery demand measures, showing that the lottery effect cannot completely explain the relation between default risk and future option returns documented in this paper. We also find that risk neutral skewness (RNskew) is negative and significant when credit rating or default probability are included in the regression. The coefficient of the two default risk measures remains statistically significant, showing that the effect of default risk on future option returns cannot be fully explained by risk neutral skewness.

Next we perform the same regressions for default probability as reported in Table 5. Univariate and bivariate regressions for call options confirm the negative and significant relation between default risk and option returns. In the next subsection of the paper, we analyze double sorted portfolios.

[10] Table IA3 in the Internet Appendix reports the same analysis for delta-hedged put option returns. The results are robust for put options.

4.4 The Role of Asset Volatility and Leverage

From our theoretical model, we derive that default risk is driven by leverage and asset volatility. The model supports the following relations: as leverage and asset volatility increase, default risk increases, and option returns decrease. We proceed to test these relations. We run Fama-MacBeth cross-sectional regressions of option returns on leverage, asset volatility, and default risk.

In Table 6, Panel A reports the results of the Fama-Macbeth cross-sectional regressions of option returns on leverage and asset volatility for all firms, for investment grade firms, and for non-investment grade firms. The results support the model predictions in all three setups: the coefficients of leverage and asset volatility are both negative and statistically significant.

When comparing the magnitude of the coefficients for investment versus non-investment grade firms, we draw the following conclusion. The coefficient of leverage is 7 times larger for non-investment grade firms than for investment grade while the coefficient of asset volatility decreases. Option returns of firms with high default risk (non-investment grade) are more sensitive to leverage than firms with low default risk. Table IA13 in the Internet Appendix reports the same analysis for delta-hedged put option returns and the results are quantitatively similar.

In Table 6, Panel B we perform Fama-MacBeth cross-sectional regressions of call option returns on leverage, asset volatility, and default risk. We include two measures of default risk: credit ratings and default probability. We regress option returns on credit ratings (regression 1) and default probability (regression 2) as well as market leverage and asset volatility. In Table 6, Panel B we observe that the coefficients of all three variables are negative and statistically significant. These results also hold for put options as reported in Table IA13 in the Internet Appendix. Table IA14 further includes two additional capital structure related variables: short-term debt ratio and long-term debt ratio. Short-term (long-term) debt ratio is long term debt due in one (five) year(s) divided by total long term debt. We find that these two measures are also significantly and negatively related to delta-hedged option returns.

Theoretically, the negative relation between default risk and option returns is driven by asset volatility and market leverage. The predictability of default risk should disappear in the presence of asset volatility and market leverage. However, the coefficient of default risk is still negative and significant. There are at least two potential explanations for this result: 1) Omitted variables and

2) non-linear relations among the variables. 1) We derive the relations among the variables using a simple stylized capital structure model. Our approach is likely omitting variables that explain option returns. Hence, the coefficient of default risk is capturing the information of these omitted variables. 2) Under our model the relation among the explanatory variables and option returns is not linear as shown in Figures A.1 and A.2. Linear regressions do not capture all the non-linearities among the variables. Even when we include asset volatility squared, market leverage squared, and the cross-product between asset volatility and market leverage, the coefficient of default risk is still significant. The combination of these two explanations seems like the most plausible reason for default risk to still predict option returns in the presence of leverage and asset volatility.

4.5 Double-Sorted Portfolios

So far we have established a strong negative relation between default risk and future delta-hedged option returns. In this section we explore the impact of default risk on the relation between future option returns and predictor variables documented in the literature. The firm characteristics are the same we used in the previous section: size, return reversal, profitability, return momentum, cash holdings, analyst forecasts, idiosyncratic volatility, volatility risk premium, the slope of the volatility term structure, the bid-ask spread, and option implied skewness (Bali and Murray (2013) and Boyer and Vorkink (2014)). Campbell, Hilscher, and Szilagyi (2008) show that distress risk is predicted by low market capitalization, high volatility, low past stock returns, low cash-to-asset ratio, low profitability and low liquidity. Therefore the predictability of default risk might be exacerbated for high/low levels of these characteristics.

At the end of each month, we perform independent double sorts using default risk and each of the firm characteristics. Next, we compute the average monthly option return for each of the 25 quintile portfolios and report the long-short default risk spread for each level of the firm characteristic.

Table 7 reports independent double sorting by credit rating and each firm characteristic. For each characteristic we report the long-short delta-hedged call option returns. When sorting by size, the long-short default risk spread is the most negative for small companies (Quintile 1) at -1.58% with a significant t-statistic of -3.36. The default risk spread monotonically increases as the firm value increases from quintile 1 to quintile 5. The returns are negative for all quintiles and are statistically significant up to quintile 4.

The results for other firm characteristics are similar. The long-short default risk spread is the largest for small firms, firms with low volatility risk premium, high bid-ask spread, high idiosyncratic volatility, low profitability, and high analyst dispersion. That the predictability of some of these existing anomalies is concentrated on high default risk firms confirms the findings by Campbell, Hilscher, and Szilagyi (2008) who show that high default risk firms have higher illiquidity, lower market capitalization, lower profitability, lower cash-to-assets ratio, higher idiosyncratic volatility, and lower past stock returns.

Since the calculation of default probability depends on volatility, default risk and volatility could be highly correlated. To address the concern about the relationship, we also consider double sorts. First we sort by realized volatility and then by credit rating or default probability. In Table IA5, we show the average return of the 5×5 portfolios first sorted by realized volatility in the past month, and then by credit rating in Panel A and default probability in Panel B. We also report the high-minus-low return in the last column. In each volatility quintile, high default risk firms have significantly lower delta-hedged option return than low default risk firms. The effect of default risk on delta-hedged option returns remains significant when studying firms with similar levels of volatility. The high-minus-low return becomes more negative when volatility is higher, suggesting that the return spread driven by default risk is indeed related to the level of volatility.

Overall, double sorted portfolios show that the long-short default spread is consistently negative and significant across existing option return predictors. Table IA4 confirms the results when double sorting by probability of default. We conclude that default risk predicts option returns across different levels of firm characteristics shown to also predict option returns. In the next subsection of the paper, we analyze the impact of credit rating announcements on option returns.

4.6 Impact of Credit Rating Announcements

We now analyze the time-series relation between default risk and future option returns by exploring how changes in default risk impact equity option returns. In the previous subsections, we document that higher levels of credit rating translate into lower option returns in the cross-section. In this section, we explore how credit rating downgrades and upgrades impact option returns.

Table 8 reports delta-hedged option returns around credit rating downgrades and upgrades. To measure the impact of credit rating announcements on option returns, we compute the average monthly option return before the downgrade for the period $[-T; -1]$ and compare it with the average option return after the downgrade for the period $[1; +T]$ for T equal to 6 and 12 months. We exclude the one-month period before the announcement $[-1; 0]$ and one-month period after the announcement $[0; 1]$ to avoid the effect of private information and behavioral biases such as overreaction. The announcement occurs in month 0. The sample includes only stock-month observations with six months or twelve months of a rating change. We report the means over all such stock-month observations before and after the announcement. The analysis is conducted for delta-hedged call option returns, delta-hedged put option returns, and implied volatility. If the announcement impacts option returns, the average return for one period before and one after should be statistically different. We report two-sample matched pair t-statistics in parentheses.

We find that after a downgrade announcement option returns significantly decrease. For example, the average call option return for the period $[-6; -1]$ before the downgrade is -0.32% per month and it decreases to -0.86% for the period $[1; +6]$ after the downgrade is announced. More importantly, the difference between the return after and before the downgrade for call options is negative at -0.54% with a t-statistic of -4.40. A similar pattern is observed for put options. The after-minus-before spread is negative and significant for calls and puts for both return windows of $[-6; +6]$ and $[-12; +12]$. This shows that increases in default risk translate into lower option returns. This decrease in option returns is accompanied by a statistically significant increase in implied volatility.

Credit rating upgrades have the opposite effect on option returns. An interesting finding is that put option returns increase after credit rating upgrades. For the window $[-12; +12]$, put option returns are negative before the announcement with a value of -0.42% and increase to -0.20% after the upgrade announcement. The after-minus-before spread is 0.22% with a t-statistic of 3.61. A similar pattern is observed for the window $[-6; +6]$. The call option after-minus-before spread is positive but insignificant. To properly conclude on the impact of upgrades on option returns, we analyze the variance risk premium of the firm since it is closely related to its delta-hedged option return. The variance risk premium is defined as the difference between realized variance for the month and implied variance observed at the end of the previous month. Note that the variance risk premium is an ex-post measure since it uses the realized variance for the month and is not to be confused with the volatility risk premium from Goyal and Saretto (2009) that uses historical volatility over the previous year.

Table IA6 reports that variance risk premiums significantly increase after a credit rating upgrade. The after-minus-before spread for the window $[-6; +6]$ ($[-12; +12]$) is 1.26% (1.25%) with a t-statistic of 3.89 (3.21). Overall, we conclude that variance risk premiums and delta-hedged option returns increase after credit rating upgrades.

Using credit rating announcements, what we try to show is that default risk is a driver of volatility risk in this specific setting, because the credit rating announcement is unlikely to be a shock to the volatility in the most direct way. Following downgrade announcements, implied volatility increases. We argue that the implied volatility increase is driven by the change in credit rating, not the other way around. Credit rating upgrades do not impact implied volatility as reported in Table 8. Implied volatility remains at the same level before and after the upgrade. Hence the impact of default risk on put option returns and variance risk premiums is not associated with changes in implied volatility, but changes in realized volatility.

We conclude that shocks to default risk impact option returns. We measure shocks to default risk using credit rating announcements. Credit rating downgrades cause call option returns and put option returns to decrease. The opposite happens for credit rating upgrades. The after-minus-before spread for upgrades is positive in all cases and significant for put option returns and variance risk premiums.

We also use panel regressions to study the impact of credit rating announcements on option returns as a robustness check. In Table IA7 Panel A, the dependent variable of the panel regression is the delta-hedged call option return and the variance risk premium. The sample only includes stock-month observations six months before and six months after a rating change. We exclude the month before the announcement and the month of the announcement. The Dummy variable equals zero for option returns before the announcement [-6, -1] and one for option returns after the announcement [1,6]. We include firm-announcement fixed effects and month fixed effects in all stock-month observations in the regressions. The regression results are reported for downgrades (upgrades) in columns 2 and 3 (4 and 5). The dummy variables are negative and statistically significant for downgrade events, showing that the results in Table 8 are robust to the specification of panel regressions after including the fixed effect. The results for upgrade events are also consistent with the results in Table 8.

It is also interesting to study whether the option returns of downgraded firms are similar to those of other firms with similar ratings, and whether there is something unique about the period after the rating change that causes options to be priced differently than options on other firms with the same rating. We conduct the analysis in Table IA7 Panel B. In Panel B, the sample includes all stock-month observations in the regular sample. The dependent variable is delta-hedged call option return. Down Before is a dummy variable, which equals one for stock-month observations that come within six months prior to a downgrade and zero for other observations. Down After is a dummy variable, which is equal to one for stock-month observations that come within six months after a downgrade and zero for other observations. Up Before and Up After are similar dummy variables for upgrades. Panel B shows that, options of downgraded firms are priced differently than options on other firms with the same rating. More specifically, we find the delta-hedged option return is more negative after the downgrade, compared with firms with the same rating. Our interpretation is that investors overreact to the downgrade event six months after the announcement. The coefficient of the dummy variable "Up Before" is positive and significant, showing that option returns before the upgrade announcements are significantly higher than options returns on other firms with the same rating. It might be the case that the information has been incorporated in the pricing of options before the upgrade announcements. Overall, we conclude that because investors may overact to downgrade events, the real impact of downgrades on option returns is smaller than the one reported in Table 8.

Lastly, to disentangle the effects of default risk and volatility risk on option returns, we consider credit rating downgrade events where implied volatility remains constant. More specifically, we consider downgrade events where the change in implied volatility is within the range of [-0.01,0.01]. We report the results in Table IA8. The results show that when implied volatility remains constant before and after the announcement, downgrade events still have a significant and negative impact on delta-hedged option returns. Hence, the effect on delta-hedged option return and variance risk premium is due to the change in realized volatility.

4.7 Robustness Tests

A clear empirical relation exists between default risk measures and delta-hedged option returns. We now explore the predictability for two subsamples: 1996-2008 and 2009-2016. The main goal is to establish if the predictability remains after the 2008 crisis. The second test we perform is motivated by Bakshi and Kapadia (2003a) who theoretically show that delta-hedged option gains are proportional to the stock price. Hence, we report the results for delta-hedged option gains scaled by the stock price (instead of using the initial investment).

Table 9 reports portfolio sorts of delta-hedged call option returns for two subperiods: 1996-2008 and 2009-2016. Panel A reports quintile portfolios sorted by credit ratings. The negative relation remains for the two subperiods. The long-short return, which is the difference between quintile 5 and quintile 1, is smaller (in absolute value) for the 2009-2016 period. The long-short return is -0.84% from 1996-2008 and -0.72% from 2009-2016, and is statistically significant in both sub-periods.

On Panel B, we perform the same analysis sorting by default probability. The negative relation is confirmed. The long-short returns are negative and significant in both subsamples but are smaller for the second subperiod: -0.72% vs -0.52%. For completeness, Table IA9 in the Internet Appendix repeats this analysis for put options. The negative relation is confirmed, and we also observe that the delta-hedged option returns are smaller (in absolute value) after the 2008 crisis.

Table 9 also reports delta-hedged call gains scaled by the stock price. The negative and significant relation between default risk and option returns is confirmed when sorting by credit ratings (Panel A) and default probability (Panel B). Put option returns display the same negative relation as reported in Table IA9.

In this section we perform two robustness tests for delta-hedged calls and puts that confirm that default risk is negatively related with future option returns. The results hold for credit risk and default probability.

4.8 Transaction Costs

The results presented so far do not include transaction costs. We investigate the impact on the long-short delta-hedged call option returns of three types of trading frictions: bid-ask spread, margin requirements and the stock short-lending fee.

To reduce the impact of transaction costs, we follow previous studies such as Goyal and Saretto (2009), Bali and Murray (2013), and Zhan et al. (2021) and hold the position for one month without rebalancing the delta hedges. We report results based on the buy-and-hold delta-hedged call option returns. Specifically, the return to selling a delta-neutral call over [t, t+1] is

$$return = \frac{\Delta_t.S_{t+1} - C_{t+1}}{\Delta_t.S_t - C_t} - 1 \tag{6}$$

where the initial investment cost is $\Delta_t.S_t - C_t > 0$, with C and S denoting the call option price and the underlying stock price, and Δ_t being the Black-Scholes call option delta at time t. The payoff at the end of the holding period is $\Delta_t.S_{t+1} - C_{t+1}$.

In the previous parts of the paper, we assume that the effective spread is equal to zero — i.e., option returns are computed with a price equal to the midpoint of the bid and ask quotes. In this section, we measure option transaction costs by the effective bid-ask spread when selling and buying the call options. Since Optionmetrics does not provide effective bid-ask spread, we assume an effective option spread that is equal to 0%, 25%, and 50% of the quoted spread. Starting from May 2003, we obtain actual effective option-bid-ask spreads using option intraday trades from Options Price Reporting Authority (OPRA) as in Muravyev and Pearson (2020).[11]

In Panel A of Table 10, we report the long-short portfolio returns sorted on credit rating using an effective spread equal to 0%, 25%, and 50% of the quoted spread. The long-short portfolio return is positive when the effective spread is equal to 0% because we long the delta-hedged portfolio in the first quintile and short the portfolio in the last quintile to analyze the profitability of the strategy. We observe that, with an effective to quoted spread of 25%, the return of the trading strategy is positive and statistically significant for all three weighting schemes. However, for an effective to quoted spread of 50%, the long-short portfolio returns turn negative.

We analyze two additional costs that impact option trading: the short-lending fee and margin requirements. Short-lending fees are to be paid when shorting a stock and margin requirements when shorting an option. The short-lending fee is the rate to be paid to short-sell a stock. We work with the implied short lending fee as in Muravyev, Pearson, and Pollet (Forthcoming).[12] We also account for the margin requirement required when writing options. The option strategy involves holding delta-shares of the underlying stock for one unit of the short call option. We follow the CBOE initial margin requirement for a short option position covered with the underlying, which is "100% of the option proceeds plus 20% of the underlying security value less out-of-the-money

[11]We thank the authors for sharing the actual effective spreads data.
[12]We thank the authors for sharing the implied short-lending fee data.

amount, if any, to a minimum for calls of 100% of the option proceeds plus 10% of the underlying security value." We assume the margin cost is the cost of borrowing the additional capital to meet the margin requirement over the holding period which is one month (Weinbaum, Fodor, Muravyev, and Cremers, 2021). We compute an adjusted return to account for short-lending costs and margin requirements of the delta-neutral call writing as follows

$$return = \frac{\Delta_t.S_{t+1} - C_{t+1} - (r/12).(M + SL)}{\Delta_t.S_t - C_t} - 1 \tag{7}$$

where r is the 1-month Libor interest rate, SL is the short-lending cost equal to $\Delta_t.S_t$, and M is the CBOE required margin. Panel A of Table 9 reports the long-short delta-hedged call writing returns that include margin and lending costs and an effective to quoted spread of 25%. The trading strategy reports positive and significant returns for all three weighting schemes. The strategy is profitable after we account for transactions costs.

In the OPRA subsample, the observed effective spread is 52% of the quoted spread. Assuming no transaction costs, the long-short return is positive and significant. Once we account for the observed bid-ask spread, the trading strategy is only significant for open-interest weighted returns. Once we account for margin and short-lending costs the strategy is no longer profitable.

We repeat this analysis for straddle returns in Table 10 Panel B. The analysis for straddles confirms the results for delta-hedged calls when no transaction costs are considered. There is a negative and significant relation between straddle returns and credit ratings. In Table 10 Panel B when the effective bid-ask spread equals to 0%, the relation is positive since we long the straddles in the first quintile and short the straddles in the last quintile to analyze the profitability of the strategy. When we account for transaction costs and consider an effective to quoted spread of 25%, the straddle strategy is no longer profitable.[13]

In conclusion, a trading strategy on the long-short delta-hedged call option writing sorted on credit ratings is profitable once we account for all transaction costs assuming that the trading strategy can be executed at an effective to quoted spread of 25%. Muravyev and Pearson (2020) document that algorithmic traders pay on average 25% of the effective to quoted spread. For a subsample after 2003, we use actual effective spreads extracted from intraday data. Using these

[13]Holding the straddle position until maturity does not make the strategy profitable after including all transactions costs.

effective spreads, the margin costs, and the short lending costs, the long-short delta-hedged call trading strategy is no longer profitable.

4.9 Default Risk and Equity Option Anomalies

In this section, we explore the impact of default risk on the relation between future option returns and predictor variables documented in the literature. Since default risk is a risk-based determinants of cross sectional variation of future option returns, it is worthwhile to examine whether default risk could help us understand other anomalies in the option market. That is, whether there exists a risk-based explanation that has the potential or could partially account for the existing anomalies in the option market. These option return predictors are size, return reversal, profitability, return momentum, cash holdings, analyst forecast dispersion (all by Zhan, Han, Cao, and Tong (2021)), volatility risk premium (Goyal and Saretto (2009)), the slope of the volatility term structure (Vasquez (2017)), idiosyncratic volatility (Cao and Han (2013)), and the bid-ask spread (Christoffersen, Goyenko, Jacobs, and Karoui (2017)).

We sort options into three portfolios with low, medium, and high default risk. Then we independently sort by each predictor into five quintiles and we report the long-short option return for each predictor for the three default risk levels.

Table 11 presents open-interest weighted long-short call option returns for each predictor.[14] The first column reproduces the results from the original papers but only includes firms with available credit rating. The long-short return preserves the sign reported in the original studies and is significant for 9 out of 10 characteristics.[15]

In nine out of ten cases, the long-short spread is higher (in absolute value) for high default risk firms. For example, the positive relation between profitability and future option returns increases across the three default risk levels. While the long-short option return for low default risk firms is -0.08%, high default risk firms report a long-short option return of 0.61%. These two long-short returns are statistically different from each other. Moreover, only the long-short option return of the high default risk firms is significant. This result is observed in five out of ten cases. For size,

[14] Table IA12 in the Internet Appendix reports the same analysis for delta-hedged put options. The results are quantitatively similar.

[15] Cash-to-assets ratio is not significant for open-interest weighted returns, but is significant for equal-weighted returns.

lagged twelve-month return, cash-to-asset ratio, profitability, and analyst dispersion the long-short spread is significant only in the tercile portfolio that contains firms with high credit risk. Also in eight out of ten cases, we observe that the long-short spread between high and low default risk firms is different from zero.

To conclude, we provide a new and unexplored dimension in understanding the profitability of established anomalies in the equity option market. In particular, we show that the profitability of some anomalies is restricted to high credit risk firms, and is nonexistent for firms with low credit risk. In all anomalies, the profitability of option anomalies is more pronounced in stocks with low credit worthiness. The results show that default risk is highly related to other option market predictors. Default risk may potentially and partially explain other anomalies with a risk-based explanation. The results are similar in spirit to those in Vassalou and Xing (2004) and Avramov et al. (2013), who study the relation between default risk and other anomalies in the stock market. Further analysis could be conducted to understand this relation in more detail. This analysis is beyond the scope of this paper and we leave it for future research.

5 Conclusion

This paper explores the relation between default risk and expected option returns, both in the cross-section and the time-series. Using the cross-section of equity option returns from Optionmetrics from 1996 to 2016, we find that the long-short option returns for stocks sorted by default risk are negative and significant. This result holds for call and put options, and is robust to different measures of default risk, namely credit ratings and default probability. We compute the alphas of the long-short option portfolios on factor models proposed by Fama and French (2015) and Bai, Bali, and Wen (2019) where we also include the market default spread factor. In all setups, the alphas are negative and significant and of the same magnitude than the raw returns.

In the time-series, we investigate how credit rating changes impact option returns. We find that credit rating downgrades (upgrades) cause delta-hedged returns to decrease (increase). More importantly, we document that implied volatility does not change after credit rating upgrades. Therefore, the increase in delta-hedged put option returns is not caused by changes in volatility but solely by changes in default risk.

A theoretical model supports our findings. Using a compound option model with jumps, we find that firms with higher default risk have lower expected delta-hedged option returns. According to our model, default risk is negatively related with expected option returns and the main drivers of this relation are leverage and asset volatility. According to our model one channel that increases default probability is volatility risk. To hedge away this variance increase in high default risk firms, option buyers are willing to pay a premium and experience more negative returns on the delta-hedged option position. Hence firms with high default risk have more negative delta-hedged option returns than firms with low default risk.

From the theoretical model, default risk is driven by leverage and asset volatility. Results from Fama-MacBeth regressions show that the drivers that affect default risk also impact option returns. Higher leverage or higher asset volatility results in more negative delta-hedged option returns. We also find that the impact of leverage on delta-hedged option returns is higher for non-investment than for investment grade firms.

We also examine the impact of default risk on the profitability of ten option market anomalies documented in the literature. Evidence based on portfolio sorts shows that, for nine out of ten anomalies, the long-short return spread is the largest for high default risk firms. For five anomalies—size, lagged twelve-month return, cash-to-asset ratio, profitability, and analyst earnings forecast dispersion—the long-short option return is significant only for the worst-rated stocks.

Overall, this paper explores one economic channel, i.e. default risk of the firm, that differentiates the pricing of expected delta-hedged option returns of individual stocks. The model indicates that the first-order equity risk can transfer to higher-order risks such as variance risk. The implications of the model help us understand the economic determinants of the cross-sectional option returns.

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A Appendix

A.1 Variables Definition

- Credit rating: Credit ratings are provided by Standard & Poor's and are mapped to 22 numerical values, where 1 corresponds to the highest rating (AAA) and 22 corresponds to the lowest rating (D).

- Default probability: Default probability is calculated using a structural KMV-Merton type model. We follow the procedure in Bharath and Shumway (2008) with the iterated estimate of the volatility of the firm value to get estimates of default probability.

- Size is defined as the natural logarithm of the market value of the firm's equity (Banz (1981) and Fama and French (1992)).

- $RET_{(-1,0)}$: The stock return reversal is the lagged one-month return (Jegadeesh (1990)).

- $RET_{(-12,-1)}$: Stock return momentum is the cumulative return on the stock over the eleven months ending at the beginning of the previous month (Jegadeesh and Titman (1993)).

- Cash-to-Assets: Cash-to-assets ratio is the value of corporate cash holdings over the value of the firm's total assets (Palazzo (2012)).

- Profitability: Profitability is earnings divided by book equity in which earnings are defined as income before extraordinary items (Fama and French (2006)).

- Analyst Disp.: Analyst earnings forecast dispersion is the standard deviation of annual earnings-per-share forecasts scaled by the absolute value of the average outstanding forecast (Diether, Malloy, and Scherbina (2002)).

- Idio. Vol.: Idiosyncratic volatility is the standard deviation of the residuals of the Fama-French three-factor model estimated using daily stock returns over the previous month (Ang, Hodrick, Xing, and Zhang (2006)).

- VRP: Volatility risk premium is the difference between historical volatility over the previous year and the Black-Scholes implied volatility for at-the-money options (Goyal and Saretto (2009)).

- VTS Slope: The slope of the volatility term structure is the difference between long-term and short-term implied volatilities (Vasquez (2017)).

- Bid-ask Spread: Bid-ask spread is defined as $2(O_{ask} - O_{bid})/(O_{bid} + O_{ask})$, where O_{bid} is the highest closing bid option price and O_{ask} is the lowest closing ask option price.

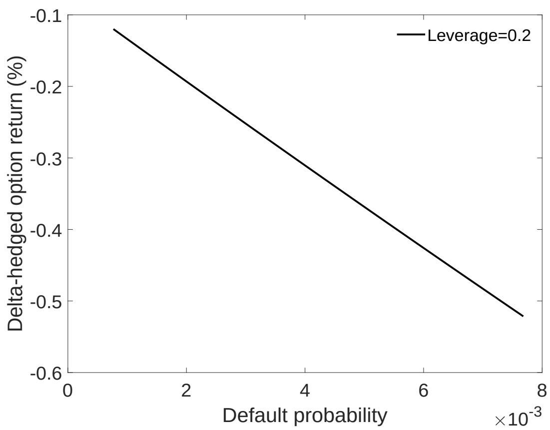
- Market leverage: Leverage is computed as the sum of total debt (data item: LTQ) and the par value of the preferred stock (data item: PSTKQ), minus deferred taxes and investment tax credit (data item: TXDITCQ), divided by market equity.

- MAX (1): Maximum daily stock return in a month (Bali, Cakici, and Whitelaw (2011)).

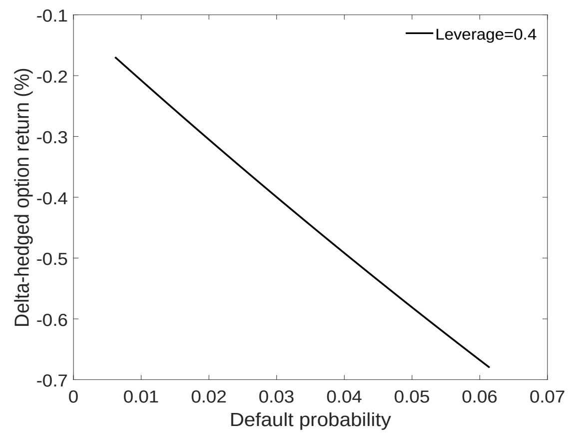
- MAX (5): Average of the five highest daily stock returns in a month (Bali, Cakici, and Whitelaw (2011)).

Figure A.1: Default Probability and Option Returns

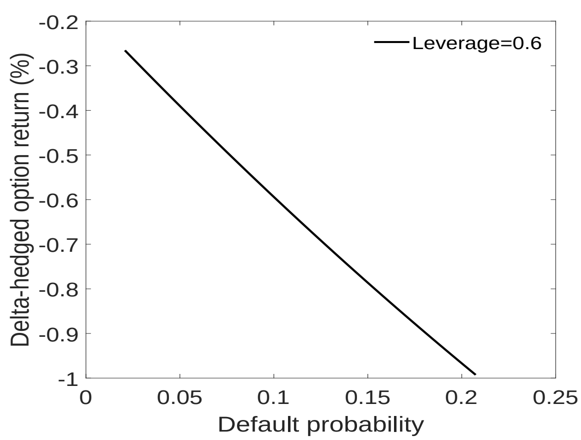
(a)



(b)

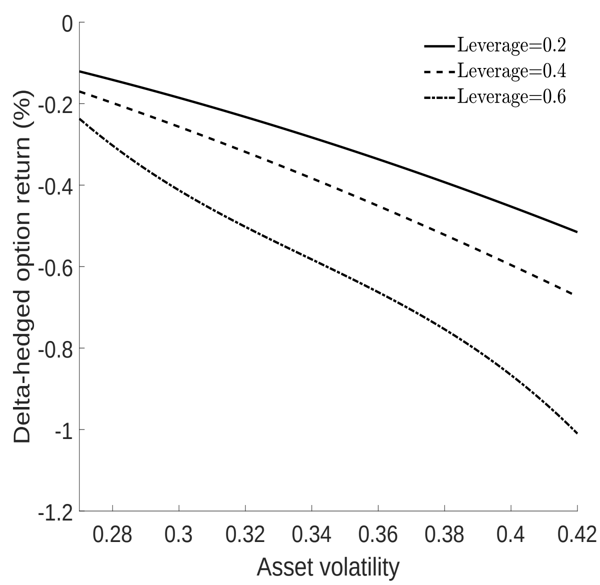


(c)



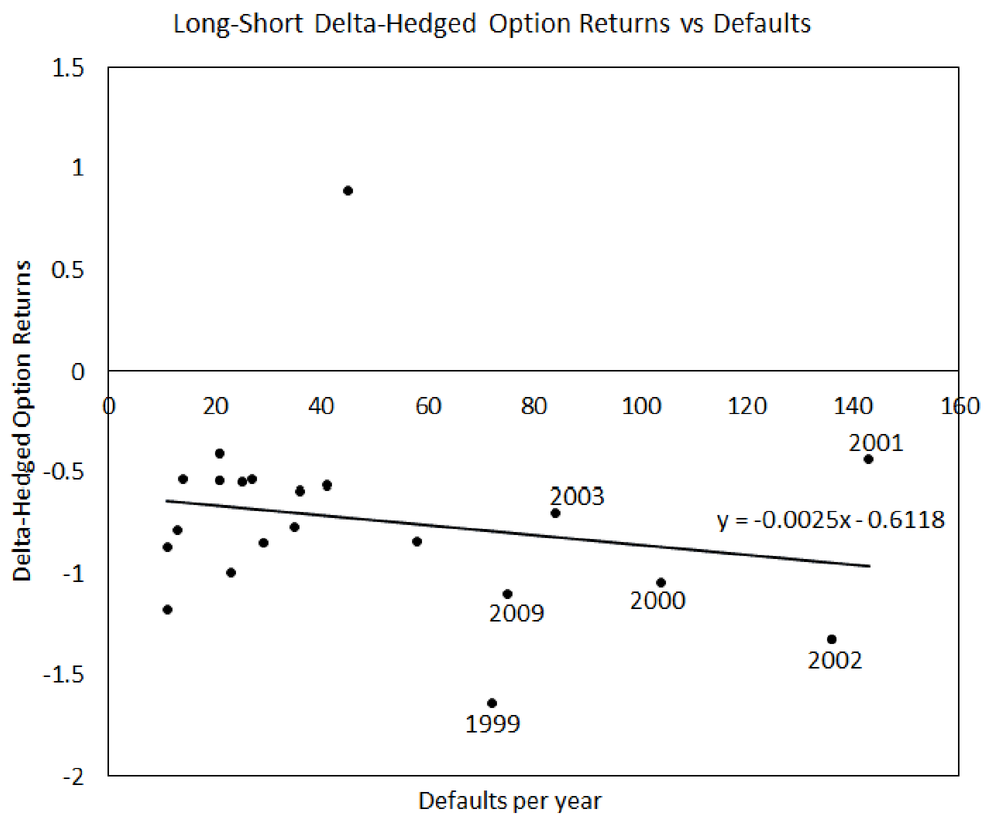
This figure plots delta-hedged option returns (%) as a function of default probability. We use numerical simulations according to our theoretical capital structure model with jumps. Figure (a), (b), and (c) plot delta-hedged option returns at varying default probabilities for three levels of leverage ratio: 0.2, 0.4, and 0.6. We vary the jump intensity λ between 0.1 and 1. We use the following input parameters for the firm's asset process: σ=0.25 (asset volatility of the firm), κ=0.35 (tax rate), r=0.02 (risk-free rate), α=0.9 (percentage of the asset value that debt holders can get upon bankruptcy), V_0=100 (initial asset value of the firm), ρ=0.5 (correlation between the diffusion terms in the asset and consumption processes), a=0.2 (risk aversion coefficient in the representative investor's power utility function), and σ_1= 0.2 (volatility of consumption process). The probabilities of positive and negative jumps in the asset return are p_u=0.3 and p_d=0.7, and the absolute means of the upward and downward jump sizes are $1/\eta_u$=1/6 and $1/\eta_d$=1/3.

Figure A.2: Delta-Hedged Option Returns Drivers: Leverage and Asset Volatility



This figure plots the delta-hedged option return (%) as a function of asset volatility for three levels of firm leverage: 0.2, 0.4, and 0.6. We use numerical simulations of the theoretical capital structure model with the following input parameters for the firm's asset process: σ=0.25 (asset volatility of the firm), κ=0.35 (tax rate), r=0.02 (risk-free rate), α=0.9 (percentage of the asset value that debt holders can get upon bankruptcy), V_0=100 (initial asset value of the firm), ρ=0.5 (correlation between the diffusion terms in the asset and consumption processes), a=0.2 (risk aversion coefficient in the representative investor's power utility function), and σ_1= 0.2 (volatility of consumption process). The probabilities of positive and negative jumps in the asset return are p_u=0.3 and p_d=0.7, and the absolute means of the upward and downward jump sizes are $1/\eta_u$=1/6 and $1/\eta_d$=1/3.

Figure A.3: Long-Short Delta-Hedged Option Returns vs Number of Defaults Per Year



This figure plots the number of defaults per year against the long-short delta-hedged call option returns per year for Optionmetrics stock options from January 1996 to April 2016. The yearly long-short option return is the average of the monthly long-short returns for the corresponding year. The number of defaults per year corresponds to the number of firms with a 'D' credit rating. According to S&P Global Ratings Definitions,"an obligation rated 'D' is in payment default. The 'D' rating also will be used upon the filing of a bankruptcy petition or the taking of a similar action if payments on an obligation are jeopardized."

Table 1: Summary Statistics

Variable	Mean	Std. Dev.	10th Pctl	25th Pctl	Median	75th Pctl	90th Pctl
Panel A: Call Options (N=216,822)							
Delta-Hedged Return (%)	-0.75	4.36	-4.45	-2.38	-0.81	0.69	2.92
Moneyness = S/K	0.98	0.03	0.94	0.96	0.98	1.00	1.01
Days to Maturity	47.65	2.99	45.00	46.00	47.00	50.00	51.00
Bid-Ask Spread	0.19	0.24	0.04	0.06	0.11	0.22	0.43
Implied Volatility	0.47	0.22	0.24	0.31	0.42	0.57	0.76
Gamma	0.10	0.08	0.03	0.05	0.08	0.13	0.20
Panel B: Put Options (N=207,082)							
Delta-Hedged Return (%)	-0.49	3.42	-3.90	-2.11	-0.69	0.75	3.00
Moneyness = S/K	1.02	0.03	0.99	1.00	1.02	1.05	1.06
Days to Maturity	44.9	7.6	31.0	45.0	47.0	50.0	51.0
Bid-Ask Spread	0.12	0.16	0.02	0.03	0.07	0.15	0.29
Implied Volatility	0.49	0.26	0.24	0.31	0.43	0.61	0.81
Gamma	0.07	0.07	0.01	0.02	0.05	0.09	0.15
Panel C: Firm Characteristics							
Credit rating	9.26	3.34	5.00	7.00	9.00	12.00	14.00
Default Probability	0.04	0.14	7.3e-48	6.1e-25	1.7e-11	7.4e-05	0.04
Leverage	0.34	0.25	0.05	0.14	0.30	0.50	0.72
Asset Volatility	0.38	0.21	0.17	0.23	0.32	0.47	0.66
Idiosyncratic Volatility	0.34	0.24	0.13	0.18	0.28	0.42	0.61
VTS Slope	-0.02	0.07	-0.08	-0.03	-0.01	0.02	0.04
VRP	-0.11	0.32	-0.50	-0.31	-0.11	0.09	0.29
Size	7.64	2.02	5.14	6.18	7.52	8.96	10.33

This table reports summary statistics of delta-hedged option returns from Optionmetrics for the period January 1996 to April 2016. Moneyness is the stock price over the strike price. Relative bid-ask spread is the difference between bid and ask option prices divided by the average of bid and ask prices. Implied volatility and gamma are provided by OptionMetrics. Credit ratings are provided by Standard & Poor's, which are mapped to 22 numerical values, where 1 corresponds to the highest rating (AAA) and 22 corresponds to the lowest rating (D). Default probability and asset volatility are calculated as in Bharath and Shumway (2008). Leverage is the sum of total debt and the par value of the preferred stock, minus deferred taxes and investment tax credit, divided by market equity. Firm characteristics also include idiosyncratic volatility, the slope of the volatility term structure as in Vasquez (2017), volatility risk premium (VRP) as defined by Goyal and Saretto (2009) and size defined as the logarithm of the firm's market capitalization.

Table 2: Correlation Matrix

	Credit rating							
Default Prob.	0.43	Default Prob.						
Leverage	0.18	0.42	Leverage					
Asset Volatility	0.38	0.15	-0.39	Asset Volatility				
Idio. Vol.	0.47	0.20	-0.20	0.57	Idio. Vol.			
VTS Slope	-0.18	-0.08	0.00	-0.12	-0.22	VTS Slope		
VRP	-0.04	0.03	-0.01	0.06	0.49	0.09	VRP	
Size	-0.49	-0.22	0.01	-0.21	-0.21	0.09	0.02	Size
Bid-Ask Spread	0.17	0.07	0.06	0.01	0.03	-0.03	-0.02	-0.23

This table presents the time series average of the cross-sectional correlations of firm characteristics for Optionmetrics stocks for the period January 1996 to April 2016. Credit ratings are provided by Standard & Poor's, which are mapped to 22 numerical values, where 1 corresponds to the highest rating (AAA) and 22 corresponds to the lowest rating (D). Default probability and asset volatility are defined as in Bharath and Shumway (2008). Leverage is the sum of total debt and the par value of the preferred stock, minus deferred taxes and investment tax credit, divided by market equity. Firm characteristics also include idiosyncratic volatility, the slope of the volatility term structure as in Vasquez (2017), volatility risk premium as defined by Goyal and Saretto (2009), size defined as the logarithm of the firm's market capitalization, and the bid-ask spread which is the difference between bid and ask divided by the average of the bid and ask option prices.

Table 3: Delta-Hedged Options Sorted on Default Risk

Panel A: Credit Rating

	1	2	3	4	5	High-Low
Credit Rating	4.53	7.13	8.94	11.03	13.83	
Equal-weighted	-0.18	-0.25	-0.31	-0.49	-0.97	-0.78***
	(-1.79)	(-2.47)	(-3.22)	(-4.38)	(-7.91)	(-10.49)
OI-weighted	-0.33	-0.41	-0.48	-0.70	-1.13	-0.79***
	(-3.50)	(-4.26)	(-4.62)	(-5.14)	(-7.70)	(-6.99)
Value-weighted	-0.20	-0.27	-0.33	-0.49	-0.92	-0.73***
	(-1.94)	(-2.64)	(-3.40)	(-4.44)	(-7.60)	(-10.04)

Panel B: Default Probability

	1	2	3	4	5	High-Low
Default Prob. ($\times$100)	7.45E-07	1.67E-02	0.06	0.7	16.01	
Equal-weighted	-0.34	-0.42	-0.64	-0.81	-1.03	-0.73***
	(-3.16)	(-3.94)	(-5.92)	(-6.64)	(-7.56)	(-6.92)
OI-weighted	-0.41	-0.47	-0.75	-0.84	-1.06	-0.65***
	(-4.20)	(-4.23)	(-7.08)	(-6.18)	(-7.73)	(-5.53)
Value-weighted	-0.31	-0.37	-0.58	-0.72	-0.92	-0.65***
	(-2.99)	(-3.56)	(-5.47)	(-6.09)	(-6.87)	(-6.39)

This table reports quintile equal-weighted, option open-interest-weighted (OI-weighted) and stock-capitalization-weighted (value-weighted) delta-hedged call option returns (in %) sorted on two measures of default risk from January 1996 to April 2016. Default risk measures are credit ratings provided in Panel A and default probability in Panel B. Credit ratings are provided by Standard & Poor's and are mapped to 22 numerical values, where 1 corresponds to the highest rating (AAA) and 22 corresponds to the lowest rating (D). Default probability is defined as in Bharath and Shumway (2008). At the end of each month, we sort options from Optionmetrics on credit rating or default probability and hold the option portfolios for one month. We report the average default risk level in the first row of each panel. Newey-West t-statistics are reported in parentheses. Significance for high-low returns at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Table 4: Risk-Adjusted High-Low Option Returns

	Credit Rating			Default Probability		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Alpha	-1.07***	-1.05***	-1.17***	-0.65***	-0.53***	-0.55***
	(-6.65)	(-6.47)	(-7.16)	(-5.46)	(-3.91)	(-4.05)
MKT	0.06	-0.02	0.03	-0.01	-0.16***	-0.17***
	(1.39)	(-0.35)	(0.51)	(-0.18)	(-3.34)	(-3.45)
SMB	-0.02	-0.09	-0.01	0.01	-0.08	-0.06
	(-0.28)	(-1.13)	(-0.10)	(0.31)	(-1.33)	(-0.98)
HML	0.02	0.04	0.04	0.14***	0.18***	0.21***
	(0.25)	(0.61)	(0.61)	(2.76)	(3.02)	(3.51)
CMA	0.22**	0.12	-0.01	-2.70	5.97	-4.46
	(2.24)	(0.97)	(-0.07)	(-0.38)	(0.56)	(-0.42)
RMW	-0.02	0.00	-0.02	-6.91	1.93	-7.64
	(-0.22)	(-0.01)	(-0.16)	(-1.24)	(0.22)	(-0.84)
MKT_Bond		0.27	0.46**		0.41**	0.53***
		(1.37)	(2.45)		(2.57)	(3.36)
DRF		-0.41***	-0.68***		-0.24**	-0.31**
		(-2.99)	(-4.71)		(-2.18)	(-2.57)
CRF		0.30***	0.23**		0.50***	0.56***
		(2.88)	(2.12)		(5.72)	(6.11)
LRF		0.09	0.66**		-0.34	-0.19
		(0.35)	(2.45)		(-1.60)	(-0.85)
DH_SP500			0.36***			0.29***
			(3.81)			(3.67)
adj. R^2	0.02	0.14	0.27	0.02	0.29	0.40

This table reports the alphas and betas of time-series regressions of equal-weighted high-low option portfolio returns sorted by credit rating and default probability on factor models. The high-low portfolios are the ones from the last column in Table 3. Model 1 includes the Fama and French (2015) five stock factors (MKT, SMB, HML, CMA and RMW). Model 2 adds four common factors in the corporate bond market as in Bai et al. (2019): the value-weighted corporate bond market excess return (MKT_Bond), the downside risk factor (DRF), the credit risk factor (CRF), and the liquidity risk factor (LRF). Model 3 adds the delta-hedged call option return of the S&P 500 index (DH_SP500). Newey-West t-statistics are reported in parentheses. Significance at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Table 5: Fama-MacBeth Regressions on Default Risk and Option Returns

	Credit Rating				Default Probability			
Control Variable	C. Rating	Control	Intercept	Adj.R^2	Default Prob.	Control	Intercept	Adj.R^2
No Control	-0.001***		0.003***	0.021	-0.005***		-0.008***	0.010
	(-11.00)		(2.92)		(-4.02)		(-6.93)	
Size	-0.001***	0.054**	-0.003	0.029	-0.002**	0.251***	-0.027***	0.030
	(-6.86)	(2.09)	(-1.03)		(-2.33)	(13.47)	(-12.88)	
$RET_{(-1,0)}$	-0.001***	0.007***	0.003**	0.031	-0.005***	0.011***	-0.009***	0.019
	(-11.87)	(3.12)	(2.43)		(-4.32)	(4.74)	(-7.55)	
$RET_{(-12,-1)}$	-0.001***	0.001	0.002**	0.034	-0.005***	-0.000	-0.009***	0.020
	(-11.13)	(1.32)	(2.05)		(-4.22)	(-0.36)	(-7.14)	
Cash-to-Assets	-0.001***	-0.002	0.003***	0.029	-0.006***	-0.017***	-0.006***	0.030
	(-11.30)	(-0.81)	(3.09)		(-5.12)	(-8.47)	(-5.01)	
Profitability	-0.001***	0.004**	0.003**	0.031	-0.004***	0.012***	-0.008***	0.021
	(-10.80)	(2.17)	(2.45)		(-3.58)	(9.43)	(-6.86)	
Analyst Disp.	-0.001***	-0.002**	0.003**	0.025	-0.004***	-0.002***	-0.008***	0.014
	(-9.64)	(-2.44)	(2.45)		(-3.63)	(-3.70)	(-6.29)	
Idio. Vol.	-0.001***	-0.011***	0.003***	0.038	-0.003**	-0.023***	-0.001	0.038
	(-8.39)	(-5.57)	(3.16)		(-2.56)	(-12.87)	(-0.51)	
VRP	-0.001***	0.016***	0.003***	0.047	-0.005***	0.021***	-0.007***	0.041
	(-10.52)	(10.03)	(2.93)		(-4.91)	(12.61)	(-6.71)	
VTS Slope	-0.001***	0.089***	0.002**	0.047	-0.004***	0.117***	-0.006***	0.043
	(-9.42)	(13.72)	(2.02)		(-2.96)	(17.02)	(-4.87)	
Bid-Ask Spread	-0.001***	-0.004***	0.003***	0.029	-0.005***	-0.012***	-0.006***	0.019
	(-10.19)	(-2.80)	(3.48)		(-3.85)	(-9.04)	(-4.94)	
MAX(1)	-0.001***	-0.023**	0.003***	0.034	-0.004***	-0.069***	-0.005***	0.028
	(-10.33)	(-2.59)	(2.61)		(-3.54)	(-8.11)	(-3.95)	
MAX(5)	-0.001***	-0.028	0.002**	0.037	-0.004***	-0.157***	-0.004***	0.030
	(-10.52)	(-1.34)	(2.40)		(-3.49)	(-7.27)	(-3.18)	
RNSkew	-0.001***	-0.001***	0.001	0.025	-0.004***	-0.001***	-0.009***	0.010
	(-9.22)	(-3.52)	(1.47)		(-3.96)	(-5.31)	(-7.36)	

This table reports Fama-MacBeth regressions of delta-hedged call option returns on default risk and control variables for Optionmetrics stock options from January 1996 to April 2016. We measure default risk with credit ratings and default probability. Credit ratings are provided by Standard & Poor's. Default probability is calculated using the iteration procedure in Bharath and Shumway (2008). Control variables are firm's market capitalization (log(Size)), lagged one month return ($RET_{(-1,0)}$), cumulative return over months two to twelve prior to the current month ($RET_{(-12,-2)}$), cash-to-assets ratio as in Palazzo (2012), profitability as in Fama and French (2006), analysts' earnings forecast dispersion as in Diether et al. (2002), idiosyncratic volatility computed as in Ang et al. (2006), volatility risk premium (VRP) as in Goyal and Saretto (2009), the slope of the volatility term structure (VTS slope) as in Vasquez (2017), the bid-ask spread defined as the difference between bid and ask option prices divided by the average of the bid and ask option prices, MAX (1) as the maximum daily return in a month, MAX (5) as the average of the five highest daily returns in a month, and RNskew as the spread between OTM put implied volatility and the average of the ATM call and put implied volatility. Newey-West t-statistics are reported in parentheses. Significance at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Table 6: Capital Structure Measures and Option Returns

Panel A: Leverage and Asset Volatility

	All Firms	Investment Grade	Non-Investment Grade
Intercept	0.007***	0.005***	0.009***
	(4.14)	(2.59)	(3.16)
Market Leverage	-0.007***	-0.004*	-0.028***
	(-3.18)	(-1.92)	(-6.55)
Asset Volatility	-0.036***	-0.033***	-0.023***
	(-13.76)	(-11.07)	(-5.89)
Adjusted R^2	0.044	0.041	0.036
Obs.	182,375	107,942	28,646

Panel B: Leverage, Asset Volatility, and Default Risk

	(1)	(2)
Intercept	0.004***	0.003
	(4.01)	(1.41)
Market Leverage	-0.003***	-0.029
	(-2.59)	(-1.10)
Asset Volatility	-0.005***	-0.021***
	(-2.65)	(-12.71)
Credit Rating	-0.001***	
	(-9.34)	
Default Probability		-0.002***
		(-2.99)
Adjusted R^2	0.038	0.040
Obs.	107,990	182,043

This table reports the results from monthly cross-sectional Fama-MacBeth regressions of delta-hedged call option returns on leverage and asset volatility for Optionmetrics stock options for the period January 1996 to April 2016. Panel A reports delta-hedged option returns for all firms, for investment and non-investment grade firms. Panel B reports delta-hedged option returns regressed on leverage, asset volatility, and default risk measures. Default risk measures are credit ratings provided by Standard & Poor's and default probability calculated as in Bharath and Shumway (2008). Investment grade companies have a credit rating of BBB- or higher, and non-investment grade companies have a credit rating below BBB-. Leverage is defined as 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 Bharath and Shumway (2008). We report average coefficients and Newey-West t-statistics in parentheses. Significance at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Table 7: High-Low Option Returns from Double Sorted Portfolios

	High-Low Call Option Returns Sorted by Credit Rating				
	1	2	3	4	5
Size	-1.58***	-1.12***	-0.65***	-0.46***	-0.17
	(-3.36)	(-3.36)	(-2.91)	(-2.82)	(-1.08)
$RET_{(-1,0)}$	-0.86***	-0.88***	-0.59***	-0.53***	-0.99***
	(-3.21)	(-4.69)	(-2.83)	(-3.45)	(-5.54)
$RET_{(-12,-1)}$	-1.30***	-0.81***	-0.96***	-0.54***	-0.54***
	(-6.19)	(-4.31)	(-4.50)	(-3.15)	(-3.43)
Cash-to-Assets Ratio	-0.88***	-0.89***	-1.05***	-0.80***	-0.29
	(-4.71)	(-4.13)	(-6.65)	(-4.42)	(-0.98)
Profitability	-0.79***	-0.87***	-0.64***	-0.44***	-0.30*
	(-3.57)	(-4.94)	(-3.11)	(-2.74)	(-1.87)
Analyst Dispersion	-0.30*	-0.53**	-0.62***	-0.77***	-0.89***
	(-1.94)	(-2.47)	(-2.84)	(-4.10)	(-4.16)
Idio. Vol.	-0.39**	-0.54***	-0.49***	-0.29	-0.69**
	(-2.47)	(-3.22)	(-2.98)	(-1.44)	(-2.55)
VRP	-1.36***	-0.24	-0.45***	-0.45**	-0.52*
	(-5.78)	(-1.52)	(-2.85)	(-2.11)	(-1.93)
VTS Slope	-0.87***	-0.67***	-0.48**	-0.47***	-0.56***
	(-3.30)	(-4.44)	(-2.47)	(-3.27)	(-3.20)
Bid-Ask Spread	-0.32**	-0.98***	-1.05***	-1.51***	-1.46***
	(-2.15)	(-5.98)	(-6.83)	(-6.66)	(-5.82)
Impl. Skew.	-0.62***	-0.83***	-0.43**	-1.17***	-1.07***
	(-3.16)	(-4.49)	(-2.07)	(-6.13)	(-4.55)

This table reports the high-low delta-hedged call option returns (in %) sorted by credit rating for the period January 1996 to April 2016. At the end of each month, we double sort options independently by credit rating and by a control variable. We report the high-low portfolio return sorted by credit rating for 5 levels of the control variable. Credit ratings are provided by Standard & Poor's, which are mapped to 22 numerical values, where 1 corresponds to the highest rating (AAA) and 22 corresponds to the lowest rating (D). Control variables are firm's market capitalization (log(Size)), lagged one month return ($RET_{(-1,0)}$), cumulative return over months two to twelve prior to the current month ($RET_{(-12,-2)}$), cash-to-assets ratio as in Palazzo (2012), profitability as in Fama and French (2006), analysts' earnings forecast dispersion as in Diether et al. (2002), idiosyncratic volatility computed as in Ang et al. (2006), volatility risk premium (VRP) as in Goyal and Saretto (2009), the slope of the volatility term structure (VTS slope) as in Vasquez (2017), the bid-ask spread defined as the difference between bid and ask option prices divided by the average of the bid and ask option prices, and implied option skew. Newey-West t-statistics are reported in parentheses. The portfolios are weighted by the option open-interest. Significance for high-low returns at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Table 8: Impact of Credit Rating Announcements on Option Returns

	Downgrades		Upgrades	
	$[-6;+6]$	$[-12;+12]$	$[-6;+6]$	$[-12;+12]$
Announcements (#)	1,126	1,228	1,073	1,127
Delta-hegded Call Option Returns				
Call Return Before Announcement $[-T;-1]$	-0.32	-0.35	-0.62	-0.62
Call Return After Announcement $[1,+T]$	-0.86	-0.90	-0.52	-0.62
After-minus-before Spread	-0.54***	-0.55***	0.10	0.00
	(-4.40)	(-5.55)	(1.21)	(0.05)
Delta-hegded Put Option Returns				
Put Return Before Announcement $[-T;-1]$	0.30	0.15	-0.42	-0.43
Put Return After Announcement $[1,+T]$	-0.34	-0.41	-0.20	-0.21
After-minus-before Spread	-0.64***	-0.56***	0.22***	0.22***
	(-5.35)	(-6.27)	(3.23)	(3.46)
Implied Volatility				
IV Before Announcement $[-T;-1]$	0.44	0.42	0.35	0.35
IV After Announcement $[1,+T]$	0.47	0.46	0.35	0.35
After-minus-before Spread	0.03**	0.04***	0.00	0.00
	(2.19)	(3.76)	(0.76)	(0.94)

This table reports average monthly delta-hedged call and put option returns (in %) around credit rating announcements for Optionmetrics stock options for the period January 1996 to April 2016. The sample include only stock-month observations with six months or twelve months of a rating change. We report the average monthly option return before the announcements $[-T;-1]$ and after the announcements $[1;T]$, for T equal to 6 and 12 months. The credit rating announcement occurs in month 0. Credit ratings are provided by Standard & Poor's, which are mapped to 22 numerical values, where 1 corresponds to the highest rating (AAA) and 22 corresponds to the lowest rating (D). Implied volatility (IV) is calculated as the average implied volatility of at-the-money call and put options with 30 days of maturity. We report two-sample matched pair t-statistics in parentheses. Significance at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Table 9: Robustness Tests

Panel A: Delta-hedged Call Returns Sorted by Credit Ratings	1	2	3	4	5	High-Low
Period: 1996 to 2008	-0.27	-0.38	-0.40	-0.53	-1.10	-0.84***
	(-2.15)	(-2.88)	(-2.82)	(-2.77)	(-5.69)	(-5.92)
Period: 2009 to 2016	-0.45	-0.47	-0.64	-1.00	-1.17	-0.72***
	(-3.04)	(-3.56)	(-4.42)	(-6.79)	(-5.22)	(-3.83)
Delta-Hedge Call Gain/S	-0.16	-0.20	-0.22	-0.33	-0.50	-0.34***
	(-3.52)	(-4.19)	(-4.13)	(-5.03)	(-7.61)	(-6.87)

Panel B: Delta-hedged Call Returns Sorted by Default Probability	1	2	3	4	5	High-Low
Period: 1996 to 2008	-0.35	-0.26	-0.59	-0.72	-1.07	-0.72***
	(-2.60)	(-1.79)	(-4.41)	(-3.85)	(-5.73)	(-4.56)
Period: 2009 to 2016	-0.53	-0.83	-1.05	-1.05	-1.05	-0.52***
	(-4.08)	(-6.27)	(-6.61)	(-6.09)	(-4.77)	(-2.69)
Delta-Hedge Call Gain/S	-0.19	-0.22	-0.34	-0.38	-0.50	-0.30***
	(-4.11)	(-4.26)	(-6.86)	(-6.06)	(-7.53)	(-5.61)

This table reports quintile delta-hedged call option portfolio returns (in %) sorted on two default risk measures for Optionmetrics stock options from January 1996 to April 2016. Default risk measures are credit ratings provided by Standard & Poor's and default probability calculated as in Bharath and Shumway (2008). Panel A (B) reports option portfolios sorted by credit rating (default probability). In each panel, we show the delta-hedged option gain scaled by its initial investment in each quantile in two samples: 1996-2008 and 2009-2016. We also report the delta-hedged option gain scaled by the stock price. Portfolios are weighted with the option's open interest. At the end of each month, we sort options on credit rating or default probability and hold the option portfolios for one month. Newey-West t-statistics are reported in parentheses. Significance for high-low returns at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Table 10: Transaction Cost Analysis for the Long-Short Return

Panel A: Delta-Hedged Call Writing Long-Short Returns (in %)

	Assumed Effective to Quoted Bid-Ask Spread				OPRA: Actual Effective Bid-Ask Spread		
Weight	No cost 0%	25%	50%	25% + Margin Cost + Lending Fee	No cost 0%	With Effective Spread	Effective Spread + Margin Cost + Lending Fee
EW	1.94***	0.48***	-0.97***	0.36***	1.89***	-0.24*	-0.48***
	(23.16)	(5.95)	(-11.60)	(2.94)	(12.72)	(-1.67)	(-3.25)
OI	1.93***	0.80***	-0.32**	1.02***	2.37***	0.64**	0.37
	(12.16)	(5.12)	(-2.07)	(3.45)	(7.28)	(2.00)	(1.16)
VW	1.81***	0.41***	-0.98***	0.35***	1.85***	-0.19	-0.39***
	(19.37)	(4.56)	(-10.55)	(2.66)	(11.46)	(-1.28)	(-2.63)

Panel B: Writing Straddle Long-Short Returns (in %)

	Assumed Effective to Quoted Bid-Ask Spread				OPRA: Actual Effective Bid-Ask Spread		
Weight	No cost 0%	25%	50%	25% + Margin Cost	No cost 0%	With Effective Spread	Effective Spread + Margin Cost
EW	3.08***	-2.53***	-8.32***	-2.75***	1.51***	-14.65***	-14.77***
	(6.43)	(-5.40)	(-17.08)	(-5.88)	(2.66)	(-15.39)	(-15.39)
OI	1.42	-2.10**	-5.69***	-2.34**	0.39	-9.65***	-9.81***
	(1.51)	(-2.24)	(-6.02)	(-2.50)	(0.36)	(-7.00)	(-7.07)
VW	2.86***	-2.45***	-7.93***	-2.68***	1.39**	-14.20***	-14.31***
	(5.48)	(-4.77)	(-14.94)	(-5.21)	(2.36)	(-14.55)	(-14.56)

This table examines the impact of transaction costs (bid-ask spreads, short-lending fees, and margin requirements) on the profitability of the high-low delta-neutral call writing option returns (in %) and straddle writing returns (in %) sorted on credit rating for Optionmetrics stock options from January 1996 to April 2016. Panel A (B) reports high-low delta-neutral call writing option (straddle writing) returns for different ratios of the effective bid-ask spread to the quoted bid-ask spread: 0% (No cost), 25%, and 50%. The margin requirement adjusted return is computed using the initial option margin requirements of the CBOE. Following Weinbaum, Fodor, Muravyev, and Cremers (2020), the margin costs equal to cost of borrowing the additional capital to meet the margin requirement. The right part of the table in Panels A and B, we repeat the analysis for the subsample starting in 2003 using the actual effective option bid-ask spread obtained from intraday option OPRA data. Portfolios are weighted equally (EW), with the option's open interest (OW), and with the capitalization of the underlying stock (VW). At the end of each month, we sort options on credit rating and hold the option portfolios for one month. Newey-west t-statistics are reported in parentheses. Significance for high-low returns at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Table 11: Default Risk and Equity Option Anomalies

		Default Risk			
	All	Low	Medium	High	High-Low
Size	1.09***	-0.01	-0.38	1.17***	1.19**
	(7.41)	(-0.03)	(-1.54)	(3.78)	(2.55)
$RET_{(-1,0)}$	0.19*	0.38**	0.05	0.18	-0.20
	(1.77)	(2.15)	(0.23)	(0.94)	(-0.70)
$RET_{(-12,-1)}$	0.26**	0.10	0.18	0.64***	0.54**
	(2.01)	(0.67)	(1.11)	(2.99)	(2.34)
Cash-to-Assets Ratio	0.12	-0.03	0.14	0.44*	0.47*
	(1.52)	(-0.32)	(0.78)	(1.82)	(1.81)
Profitability	0.50***	-0.08	0.12	0.61***	0.69***
	(4.20)	(-0.58)	(0.94)	(2.90)	(3.15)
Analyst Dispersion	-0.37***	-0.01	0.13	-0.37**	-0.34*
	(-3.54)	(-0.05)	(0.87)	(-2.16)	(-1.88)
Idio. Vol.	-0.69***	-0.51**	-0.58***	-0.93***	-0.46*
	(-5.44)	(-2.48)	(-3.53)	(-4.37)	(-1.78)
VRP	0.70***	0.62***	0.78***	1.25***	0.63**
	(5.40)	(4.50)	(4.88)	(4.85)	(2.54)
VTS Slope	0.93***	0.81***	0.66***	1.21***	0.40
	(8.14)	(5.34)	(4.42)	(6.01)	(1.62)
Bid-Ask Spread	-0.19*	0.47***	0.16	-0.64***	-1.11***
	(-1.72)	(2.77)	(1.25)	(-3.07)	(-4.33)

This table reports long-short delta-hedged call option returns (in %) for option anomalies for Optionmetrics stock options for the period January 1996 to April 2016. The first column reports the long-short return for each anomaly sorted by quintiles. In the other columns we report the long-short return of each anomaly for low, medium, and high default risk. We perform independent sorts by default risk (3 groups) and by each option market anomaly (5 groups). We report the long-short portfolio that buys quintile 5 and sells quintile 1. The last column reports the difference between high and low default risk portfolios. Default risk is measured with credit ratings provided by Standard & Poor's, which are mapped to 22 numerical values, where 1 corresponds to the highest rating (AAA) and 22 corresponds to the lowest rating (D). The anomalies we report are the firm's market capitalization (Size), lagged one-month return ($RET_{(-1,0)}$), lagged 12-month return ($RET_{(-12,-2)}$), cash-to-assets ratio as in Palazzo (2012), profitability as in Fama and French (2006), analyst earnings forecast dispersion as in Diether et al. (2002), idiosyncratic volatility computed as in Ang et al. (2006), volatility risk premium (VRP) as in Goyal and Saretto (2009), the slope of the volatility term structure (VTS slope) as in Vasquez (2017), and the bid-ask option spread defined as the difference between bid and ask prices divided by the average of the bid and ask prices. Newey-West t-statistics are reported in parentheses. Significance at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

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IA Internet Appendix

IA.1 Proof of Proposition 1

By Ito's lemma, under the physical distribution the option price is equal to

$$O_t = O_0 + \int_0^t \frac{\partial O}{\partial u} du + \int_0^t \frac{\partial O_u}{\partial S_u} dS_u^c + \frac{1}{2}\int_0^t \frac{\partial^2 O_u}{\partial S_u^2} dS_u^c dS_u^c + \sum_{0<u<t} (O(S_u) - O(S_{u-})), \tag{8}$$

where dS_u^c is the continuous part of dS_u. The last term of Equation (8) represents the movement of the option price due to discontinuous jumps from time 0 to t. $O(S_u)$ is the option price evaluated at S_u, the stock price immediately after a jump, and $O(S_{u-})$ is the option price 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):

$$rO_t = \frac{\partial O_t}{\partial t} + \frac{\partial O_t}{\partial S_t}\mu_{S_t}^Q S_t + \frac{1}{2}\frac{\partial^2 O_t}{\partial S_t^2}(\sigma_{S_t}^Q)^2 S_t^2 + \lambda^Q E^Q[O(S_t) - O(S_{t-})]. \tag{9}$$

Combining Equations (8) and (9), the option price can be expressed as

$$\begin{aligned} O_t = O_0 + \int_0^t \frac{\partial O_u}{\partial S_u} dS^c + \int_0^t (rO_u - \frac{\partial O_u}{\partial S_u}\mu_S^Q S_u - \lambda^Q E^Q[O(S_u) - O(S_{u-})])dt \\ + \sum_{0<u<t} (O(S_u) - O(S_{u-})), \end{aligned} \tag{10}$$

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

$$\begin{aligned} E(\Pi_t) &= E(O_t - O_0 - \int_0^t \frac{\partial O_u}{\partial S_u} dS_u - \int_0^t r(O_u - \frac{\partial O_u}{\partial S_u} S_u du)) \\ &= E[\int_0^t \{-\lambda^Q E^Q[O(S_u) - O(S_{u-})] + \lambda^Q E^Q[(S(V) - S(V_-))\frac{\partial O_u}{\partial S_u}] \\ &\quad - \lambda E[(S(V) - S(V_-))\frac{\partial O_u}{\partial S_u}] + \lambda E[O(S_u) - O(S_{u-})]\} dt]. \end{aligned} \tag{11}$$

Note that the dS_u term in the first line of Equation (11) is the total change in the stock price including both the continuous and discontinuous parts.

We expand the first part of Equation (11) in Taylor series as follows

$$E^Q[O(S) - O(S_-)] \approx E^Q[\frac{\partial O}{\partial S}(S - S_-) + \frac{1}{2}\frac{\partial^2 O}{\partial S^2}(S - S_-)^2]. \quad (12)$$

Similarly, under the physical measure, we approximate the expected change of the option price as

$$E[O(S) - O(S_-)] \approx E[\frac{\partial O}{\partial S}(S - S_-) + \frac{1}{2}\frac{\partial^2 O}{\partial S^2}(S - S_-)^2]. \quad (13)$$

We substitute Equation (12) and (13) into Equation (11) to get Equation (4) in Proposition 1. The quadratic term in Equation (1) can be approximated by Taylor series as in

$$(S(V) - S(V_-))^2 \approx (\frac{\partial S}{\partial V}(V - V_-) + \frac{1}{2}\frac{\partial^2 S}{\partial V^2}(V - V_-)^2)^2. \quad (14)$$

We drop the higher order terms that are less relevant and simplify Equation (4) to

$$\begin{aligned} E(\Pi_t) &\approx E[\int_0^t \frac{1}{2}\frac{\partial^2 O_u}{\partial S_u^2}(\frac{\partial S_u}{\partial V_u})^2(\lambda E[V_u - V_{u-}]^2 - \lambda^Q E^Q[V_u - V_{u-}]^2)du] \\ &= E[\int_0^t \frac{1}{2}\frac{\partial^2 O_u}{\partial S_u^2}(\frac{\partial S_u}{\partial V_u})^2(V_{u-})^2(\lambda E[J-1]^2 - \lambda^Q E^Q[J-1]^2)du]. \end{aligned} \quad (15)$$

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. Given that the total variances of the asset return under the physical and risk neutral measures are

$$(\sigma_v^P)^2 = \sigma^2 + \lambda E[J-1]^2 \text{ and } (\sigma_v^Q)^2 = \sigma^2 + \lambda^Q E^Q[J-1]^2, \quad (16)$$

the expected delta-hedged gain can be rewritten as

$$E(\Pi_t) \approx E[\int_0^t \frac{1}{2}\frac{\partial^2 O_u}{\partial S_u^2}(\frac{\partial S_u}{\partial V_u})^2(V_{u-})^2((\sigma_v^P)^2 - (\sigma_v^Q)^2)du] \tag{17}$$

$$= E[\int_0^t \frac{1}{2}\frac{\partial^2 O_u}{\partial S_u^2}\,\epsilon_v^2\,((\sigma_v^P)^2 - (\sigma_v^Q)^2)\,S_u^2 du] \tag{18}$$

where $\epsilon_v = \frac{\partial S_u}{\partial V_u}\frac{V_u}{S_u}$.

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) and is equal to

$$[\log(S), \log(S)]_{(0,t]} = \int_0^t (\frac{\partial S_s}{\partial V_s}\frac{V_s}{S_s}\sigma)^2 ds + \sum_{0<s\leq t}(\frac{S_s - S_{s-}}{S_s})^2. \tag{19}$$

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

$$\begin{aligned} EVRP &= E^P[[\log(S), \log(S)]_{(0,t]}] - E^Q[[\log(S), \log(S)]_{(0,t]}] \\ &\approx \int_0^t (\frac{1}{S_u})^2(\frac{\partial S_u}{\partial V_u})^2(\lambda E[V_u - V_{u-}]^2 - \lambda^Q E^Q[V_u - V_{u-}]^2)du \\ &= \int_0^t (\frac{V_u}{S_u})^2(\frac{\partial S_u}{\partial V_u})^2(\lambda E[J_u - 1]^2 - \lambda^Q E^Q[J - 1]^2)du. \end{aligned} \tag{20}$$

The second equality uses the Taylor expansion from Equation (14). Ignoring the movements in the stock price S, the delta-hedged option return is equal to

$$E(\Pi_t) = E[\int_0^t \frac{1}{2}\frac{\partial^2 O_u}{\partial S_u^2}\frac{dEVRP}{dt}S_u^2 du]. \tag{21}$$

The above equation shows that the delta-hedged option gain or the scaled delta-hedged option return is closely related to equity variance risk premium, but it is not a perfect or clean measure of the variance risk premium because the stock price and the option gamma are time-varying.

IA.2 Measure transformation and valuation of the firm's equity in the simulation study

To simulate delta-hedged option returns under the physical measure, we require the dynamics of firm's asset process under the physical and risk-neutral measures. In this section, we derive the measure transformation of the asset process of the firm and the valuation of the firm's equity. We assume a general pricing kernel based on the utility function $U(c_t) = \frac{c_t^\alpha}{\alpha}$, where $0 < \alpha < 1$ and c_t represents consumption of the economy. In a typical rational economy, the consumption c_t follows a jump-diffusion process as follows

$$\frac{dc_t}{c_t} = \mu^m dt + \sigma^m dW_t^m + d(\sum_{i=1}^{N_t^m}(J_i^m - 1)), \tag{22}$$

where $\{N_t^m, t \geq 0\}$ is a Poisson process with jump intensity λ^m and $\{J_i^m\}$ is a sequence of independent identically distributed non-negative random variables where $Y = \ln(J_i^m)$ has a double-exponential density given by

$$f_Y(y) = p_u^m \eta_u^m e^{-\eta_u^m y}\mathbf{1}_{y\geq 0} + p_d^m \eta_d^m e^{\eta_d^m y}\mathbf{1}_{y<0},\ \eta_u^m > 1, \eta_d^m > 1, p_u^m + p_d^m = 1. \tag{23}$$

Y has a mixed distribution defined as

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

where x^+ and x^- are exponential random variables with means $\frac{1}{\eta_u^m}$ and $\frac{1}{\eta_d^m}$. The parameter m embeds the drivers of aggregate consumption and is considered a proxy of the market factor. The Radon-Nikodym derivative for the change of measure, $dQ/dP = Z_t/Z_0$, is a martingale under P given by

$$Z_t = e^{rt}c_t^{\alpha-1} = exp(-\lambda^m \xi^{(\alpha-1)} - \frac{1}{2}(\sigma^m)^2(\alpha-1)^2 + \sigma^m(\alpha-1)W_t^m)\prod_{i=1}^{N_t^m} J_i^m, \tag{24}$$

where

$$\xi^{(\alpha)} = E[(J_i^m)^\alpha - 1] = E[e^{\alpha Y} - 1] = \frac{p_u^m \eta_u^m}{\eta_u^m - \alpha} + \frac{p_d^m \eta_d^m}{\eta_d^m + \alpha} - 1. \tag{25}$$

We assume that the asset value V_t follows a double exponential jump-diffusion process under the physical measure that evolves according to

$$\frac{dV_t}{V_t^-} = \mu dt + \sigma dW_t + d(\sum_{i=1}^{N_t}(J_i - 1)), \tag{26}$$

where $dW_t = \rho\, dW_t^m + \sqrt{1-\rho^2} dW_t^\epsilon$, $\rho \in [0,1)$, W_t^m and W_t^ϵ are independent standard Brownian processes. The number of jumps in the firm's asset is equal to the number of systematic jumps, $N_t = N_t^m$, and the jump intensity is equal to that of the market, $\lambda = \lambda^m$. The jump size in the firm's asset process is driven by systematic jumps such that $J_i = J_{mi}^\beta$, where β is the sensitivity of jumps in the firm's asset process to systematic jumps and follows a double exponential Poisson distribution with probabilities $p_u = p_u^m$ to jump up and $p_d = p_d^m$ to jump down. The means of the positive and negative jump sizes are $\frac{1}{\eta_u} = \frac{\beta}{\eta_u^m}$ and $\frac{1}{\eta_d} = \frac{\beta}{\eta_d^m}$. In this model idiosyncratic jump and diffusion risks are not priced. In the simulation study, we assume that $\beta = 1$.

Using the Radon-Nikodym derivative in Equation (24) and the Girsanov theorem with jump diffusion process, the asset process under the risk neutral measure Q is defined as

$$\frac{dV_t}{V_t^-} = (r - \lambda^Q(E^Q(J_i - 1)))dt + \sigma dW^Q + d(\sum_{i=1}^{N_t^Q}((J_i^Q) - 1)), \tag{27}$$

where W_t^Q is a new Brownian process under Q defined as $W_t^Q = W_t - \rho\sigma_m(\alpha - 1)t$, N_{mt}^Q is a new Poisson process with jump intensity $\lambda^Q = \lambda + \lambda_m \xi^{(\alpha-1)}$, and $J_i^Q = (J_{mi}^Q)^\beta$. J_{mi}^Q are independent identically distributed random variables with the following density

$$f_{J_{mi}}^Q(x) = \frac{1}{1 + \xi^{(\alpha-1)}} x^{\alpha-1} f_{J_{mi}}(x). \tag{28}$$

Under the risk neutral measure, J_i^Q follows a new double exponential Poisson process with parameters p_u^Q, p_d^Q, η_u^Q and η_d^Q defined as

$$\eta_u^Q = \eta_u - \alpha + 1, \quad \eta_d^Q = \eta_d + \alpha - 1,$$
$$p_u^Q = \frac{p_u \eta_u}{(\xi^{(\alpha-1)} + 1)(\eta_u - \alpha + 1)}, \quad \text{and} \quad p_d^Q = \frac{p_d \eta_d}{(\xi^{(\alpha-1)} + 1)(\eta_d + \alpha - 1)}.$$

Next, we provide analytic forms for debt and equity value of the firm, which are used in the numerical study. Instead of assuming that default is only possible at maturity in Section 2, we assume that 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. We also assume that the firm pays a non-negative coupon, c, per instant of time when the firm is solvent.

Based on the distribution of default time and the joint distribution of default threshold and default time, we obtain the value of total assets, debt, and equity value of the firm. The total market value of the firm is the firm asset value plus the tax benefit minus the bankruptcy cost, which depends on the asset value of the firm V and the bankruptcy threshold V_B as in

$$\begin{aligned} v(V, V_B) &= V + E[\int_0^\tau \kappa \rho P e^{-rt} dt] - (1 - \alpha_d) E[V_\tau e^{-r\tau}] \\ &= V + \frac{\kappa c}{r}(1 - d_1(\frac{V_B}{V})^{\gamma_1} - d_2(\frac{V_B}{V})^{\gamma_2}) - (1 - \alpha_d) V_B (c_1(\frac{V_B}{V})^{\gamma_1} + c_2(\frac{V_B}{V})^{\gamma_2}), \end{aligned} \tag{29}$$

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 $d_2 = \frac{\gamma_2 - \eta_d}{\gamma_2 - \gamma_1}\frac{\gamma_1}{\eta_d}$. γ_1, γ_2, $-\gamma_3$ and $-\gamma_4$ are four roots from the following equation:

$$r = -(r - \frac{1}{2}\sigma^2 - \lambda\xi)x + \frac{1}{2}\sigma^2 x^2 + \lambda(\frac{p_u \eta_u}{\eta_u - x} + \frac{p_d \eta_d}{\eta_d + x} - 1), \tag{30}$$

where $0 < \gamma_1 < \eta_d < \gamma_2$ and $0 < \gamma_3 < \eta_u < \gamma_4$.

The value of total debt at time 0 is the sum of the expected coupon payment before bankruptcy and the expected payoff upon bankruptcy as in

$$D(V;V_B) = E[\int_0^\tau e^{-rt}cdt + \alpha_d e^{-r\tau}V_\tau] \tag{31}$$
$$= \frac{c}{r}(1 - d_1(\frac{V_B}{V})^{\gamma_1} - d_2(\frac{V_B}{V})^{\gamma_2}) + \alpha_d V_B(c_1(\frac{V_B}{V})^{\gamma_1} + c_2(\frac{V_B}{V})^{\gamma_2}).$$

The total equity value is the difference between the total asset value and the total debt value and is defined as

$$S(V;V_B) = v(V;V_B) - D(V;V_B) \tag{32}$$
$$= V + aV^{-\gamma_1} + bV^{-\gamma_2} - \frac{(1-\kappa)c}{r}.$$

where $a = \frac{(1-\kappa)cd_1}{r}V_B^{\gamma_1} - c_1V_B^{\gamma_1+1}$ and $b = \frac{(1-\kappa)cd_2}{r}V_B^{\gamma_2} - c_2V_B^{\gamma_2+1}$. The probability of default under this model is

$$P(\tau \leq T) = \lambda T p_d(\frac{V_B}{V})^{\eta_d} + o(T). \tag{33}$$

In the simulation study, we simulate the firm's asset process using the dynamics in Equation (26) and Equation (27) under the physical and the risk-neutral measures. The corresponding equity values are obtained from Equation (32) and the default probability is obtained from Equation (33). We then evaluate equity options as the expected payoff at the maturity under the risk neutral measure and delta-hedge the equity option with its underlying equity under the physical measure. The delta-hedge is updated daily.

IA.3 Simulation Details

In this subsection, we provide details about the simulation that are used to generate the graphs in this paper. First, we set the initial value of the firm's asset to $V_0 = 100$ and simulate $50,000$ paths of daily asset returns under the physical- and risk-neutral measures. In each path, there are 21 daily returns that correspond to one calendar month. Second, we compute the equity value of the firm for different levels of the leverage ratio (0.2, 0.4, and 0.6) for each day and each path under the physical measure. Third, we compute the equity option value at the beginning of the period as the discounted average option payoff at the end of the month under the risk-neutral measure. Finally, we construct a delta-hedged portfolio that consists of buying an at-the-money equity call option and selling delta shares of the stock. The delta position is rebalanced daily.

We use the following parameters in the simulations. Asset volatility of the diffusive part σ is equal to 0.25, which is the median asset volatility of US firms reported in Choi and Richardson (2016) and Correia, Kang, and Richardson (2018). The risk aversion coefficient a is set to 0.2 following Bliss and Panigirtzoglou (2004) who estimate the risk aversion coefficient of the power utility function from S&P 500 index options. The tax rate κ is 0.35, the risk-free rate is 2%, and the volatility of the consumption process σ_1 is 0.2. The input parameters in the jump component of the firm's asset process are p_u=0.3 and p_d=0.7, which are the probabilities of a positive and a negative jump. The absolute means of the upward ($1/\eta_u$) and downward jumps ($1/\eta_d$) are 1/6 and 1/3. These jump parameters imply that the stock has negative jumps on average.

Table IA1: Delta-Hedged Put Option Portfolios Sorted on Default Risk

	1	2	3	4	5	High-Low
			Panel A: Credit Rating			
Equal-weighted	-0.12	-0.17	-0.19	-0.36	-0.65	-0.53***
	(-1.24)	(-1.55)	(-1.83)	(-3.15)	(-4.84)	(-7.01)
OI-weighted	-0.17	-0.23	-0.25	-0.49	-0.91	-0.74***
	(-1.50)	(-1.90)	(-2.14)	(-4.03)	(-6.23)	(-6.49)
Value-weighted	-0.12	-0.15	-0.18	-0.35	-0.62	-0.51***
	(-1.18)	(-1.43)	(-1.71)	(-3.08)	(-4.66)	(-6.94)
			Panel B: Default Probability			
Equal-weighted	-0.17	-0.30	-0.40	-0.56	-0.75	-0.58***
	(-1.57)	(-2.76)	(-3.53)	(-4.42)	(-5.21)	(-6.29)
OI-weighted	-0.25	-0.30	-0.49	-0.55	-0.72	-0.47***
	(-2.55)	(-2.74)	(-4.37)	(-4.37)	(-4.49)	(-3.94)
Value-weighted	-0.15	-0.26	-0.36	-0.50	-0.66	-0.51***
	(-1.47)	(-2.46)	(-3.23)	(-4.03)	(-4.68)	(-5.77)

This table reports quintile equal-weighted, option open-interest-weighted (OI-weighted), and stock capitalization weighted (value-weighted) delta-hedged put option portfolio returns (in %) sorted on two default risk measures for Optionmetrics stock options from January 1996 to April 2016. Default risk measures are credit ratings provided by Standard & Poor's and default probability calculated as in Bharath and Shumway (2008). Panel A (B) reports option portfolios sorted by credit rating (default probability). At the end of each month, we sort options on credit rating or default probability and hold the option portfolios for one month. We report the average default risk level in the first row of each panel. Newey-West t-statistics are reported in parentheses. Significance for high-low returns at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Table IA2: Delta-hedged Call Options Sorted on Credit Rating in Five Categories

		1	2	3	4	5	High-Low
Rating Number		$1-4$ IG	$5-7$ IG	$8-10$ IG	$11-13$ NIG	>13 NIG	
Equal-weighted	Raw Return	-0.16	-0.22	-0.33	-0.66	-1.13	-0.97***
		(-1.46)	(-2.30)	(-3.32)	(-5.82)	(-7.54)	(-9.10)
	Alpha	0.08	-0.03	-0.12	-0.44	-0.86	-0.93***
		(0.46)	(-0.20)	(-0.81)	(-2.99)	(-4.85)	(-7.27)
OI-weighted	Raw Return	-0.22	-0.41	-0.53	-0.76	-1.18	-0.96***
		(-1.75)	(-4.52)	(-5.06)	(-5.61)	(-6.28)	(-5.55)
	Alpha	0.03	-0.26	-0.32	-0.47	-0.83	-0.87***
		(0.20)	(-2.07)	(-2.16)	(-2.74)	(-3.85)	(-4.28)

This table reports quintile equal-weighted and option open-interest-weighted (OI-weighted) delta-hedged call option returns (in %) and their associated alphas sorted on credit rating into five categories for Optionmetrics stock options from January 1996 to April 2016. Credit ratings are provided by Standard & Poor's and are mapped to 22 numerical values, where 1 corresponds to the highest rating (AAA) and 22 corresponds to the lowest rating (D). We report the assigned credit ratings in each group in the second row. Each month we group options into five categories: group 1: AAA, AA+, AA, AA-; group 2: A-, A, A+; group 3: BBB-, BBB, BBB+; group 4: BB+, BB, BB-; group 5: below BB-. IG is investment grade and NIG is non-investment grade. Alphas are calculated using a factor model including the delta-hedged call option return of the S&P 500. Newey-West t-statistics are reported in parentheses. Significance for high-low returns at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Table IA3: Fama-MacBeth Regressions on Default Risk and Put Option Returns

	Credit Rating				Default Probability			
Control Variable	C. Rating	Control	Intercept	Adj.R^2	Default Prob.	Control	Intercept	Adj.R^2
No Control	-0.001***		0.002**	0.020	-0.003***		-0.006***	0.006
	(-7.42)		(2.12)		(-4.46)		(-4.51)	
Size	-0.000***	0.042*	-0.003	0.028	-0.001**	0.192***	-0.020***	0.026
	(-5.73)	(1.85)	(-0.90)		(-2.33)	(10.70)	(-8.81)	
$RET_{(-1,0)}$	-0.001***	-0.004	0.002**	0.030	-0.004***	-0.004*	-0.006***	0.015
	(-8.80)	(-1.52)	(2.28)		(-5.29)	(-1.72)	(-5.32)	
$RET_{(-12,-1)}$	-0.001***	0.001*	0.002*	0.029	-0.003***	0.001	-0.006***	0.017
	(-7.81)	(1.75)	(1.93)		(-4.23)	(1.37)	(-4.50)	
Cash-to-Assets	-0.001***	-0.001	0.002**	0.026	-0.004***	-0.014***	-0.004***	0.026
	(-7.70)	(-0.63)	(2.22)		(-5.66)	(-8.45)	(-3.11)	
Profitability	-0.001***	0.003**	0.002*	0.028	-0.003***	0.008***	-0.005***	0.016
	(-7.13)	(2.37)	(1.78)		(-4.14)	(7.69)	(-4.43)	
Analyst Disp.	-0.001***	-0.001	0.002**	0.026	-0.003***	-0.002***	-0.005***	0.011
	(-6.87)	(-1.54)	(2.03)		(-3.97)	(-4.16)	(-3.99)	
Idio. Vol.	-0.000***	-0.008***	0.003***	0.036	-0.002**	-0.018***	0.000	0.035
	(-6.47)	(-3.87)	(2.65)		(-2.59)	(-9.97)	(0.41)	
VRP	-0.001***	0.014***	0.002***	0.042	-0.004***	0.017***	-0.004***	0.032
	(-7.06)	(11.15)	(2.79)		(-5.94)	(13.47)	(-3.83)	
VTS Slope	-0.000***	0.076***	0.002	0.048	-0.002***	0.077***	-0.004***	0.033
	(-5.88)	(12.22)	(1.51)		(-3.03)	(13.19)	(-3.09)	
Bid-Ask Spread	-0.001***	0.001	0.002*	0.030	-0.003***	-0.003*	-0.005***	0.015
	(-7.55)	(0.73)	(1.95)		(-4.50)	(-1.80)	(-4.25)	
MAX(1)	-0.001***	-0.032**	0.005***	0.042	-0.003***	-0.054***	-0.003***	0.048
	(-9.33)	(-2.84)	(2.41)		(-2.89)	(-7.31)	(-3.78)	
MAX(5)	-0.001***	-0.025	0.018**	0.037	-0.004***	-0.157***	-0.004***	0.025
	(-10.52)	(-1.34)	(2.38)		(-3.36)	(-7.51)	(-3.32)	
RNSkew	-0.001***	-0.001***	0.002	0.028	-0.003***	-0.001***	-0.008***	0.010
	(-8.72)	(-3.79)	(1.29)		(-4.05)	(-5.27)	(-7.53)	

This table reports Fama-MacBeth regressions of delta-hedged put option returns on default risk and control variables for Optionmetrics stock options from January 1996 to April 2016. We measure default risk with credit ratings and default probability. Credit ratings are provided by Standard & Poor's, which are mapped to 22 numerical values where 1 corresponds to the highest rating (AAA) and 22 corresponds to the lowest rating (D). Default probability (Log(Default Prob.)/100) is calculated using the iteration procedure in Bharath and Shumway (2008). Control variables are firm's market capitalization (log(Size)), lagged one month return ($RET_{(-1,0)}$), cumulative return over months two to twelve prior to the current month ($RET_{(-12,-2)}$), cash-to-assets ratio as in Palazzo (2012), profitability as in Fama and French (2006), analysts' earnings forecast dispersion as in Diether et al. (2002), idiosyncratic volatility computed as in Ang et al. (2006), volatility risk premium (VRP) as in Goyal and Saretto (2009), the slope of the volatility term structure (VTS slope) as in Vasquez (2017), the bid-ask option spread defined as the difference between bid and ask prices divided by the average of the bid and ask prices, MAX (1) as the maximum daily return in a month, MAX (5) as the average of the five highest daily returns in a month, and RNskew as the spread between OTM put implied volatility and the average of the ATM call and put implied volatility. Newey-West t-statistics are reported in parentheses. Significance at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Table IA4: Long-Short Option Returns from Double Sorted Portfolios

	Long-Short Call Option Returns Sorted by Default Probability				
	1	2	3	4	5
Size	-1.02***	-0.88***	-0.39*	-0.63***	-0.08
	(-2.92)	(-3.77)	(-1.74)	(-3.33)	(-0.54)
$\text{RET}_{(-1,0)}$	-0.81***	-0.55***	-0.44**	-0.62***	-0.99***
	(-3.20)	(-3.50)	(-2.19)	(-4.26)	(-5.21)
$\text{RET}_{(-12,-1)}$	-0.76***	-0.44**	-0.50***	-0.45**	-0.68***
	(-3.02)	(-2.39)	(-3.71)	(-2.59)	(-3.09)
Cash-to-Assets Ratio	-0.76***	-0.80***	-0.73***	-0.45***	-1.41***
	(-5.48)	(-3.89)	(-4.23)	(-2.82)	(-4.59)
Profitability	-0.84***	-0.51***	-0.20	-0.33**	-0.45***
	(-2.98)	(-2.92)	(-0.99)	(-2.54)	(-2.90)
Analyst Dispersion	-0.60***	-0.41**	-0.27	-0.52**	-0.50**
	(-3.28)	(-2.16)	(-1.50)	(-2.54)	(-2.06)
Idio. Vol.	-0.01	-0.14	-0.29*	-0.59***	-0.97***
	(-0.10)	(-1.15)	(-1.81)	(-2.90)	(-3.07)
VRP	-0.95***	-0.02	-0.09	-0.35**	-0.70***
	(-3.61)	(-0.11)	(-0.66)	(-2.05)	(-2.89)
VTS Slope	-0.69**	-0.40**	-0.56***	-0.56***	-0.26*
	(-2.48)	(-2.12)	(-4.17)	(-3.57)	(-1.80)
Bid-Ask Spread	-0.21	-0.70***	-1.05***	-1.44***	-1.55***
	(-1.56)	(-3.90)	(-5.49)	(-6.16)	(-6.60)
Impl. Skew.	-0.56***	-0.64***	-0.76***	-0.77***	-0.71***
	(-3.36)	(-3.10)	(-3.88)	(-3.74)	(-3.87)

This table reports the long-short delta-hedged call option returns (in %) sorted by credit rating for the period January 1996 to April 2016. At the end of each month, we double sort options independently by credit rating and by a control variable. We report the long-short portfolio return sorted by credit rating for 5 levels of the control variable. Credit ratings are provided by Standard & Poor's, which are mapped to 22 numerical values, where 1 corresponds to the highest rating (AAA) and 22 corresponds to the lowest rating (D). Control variables are firm's market capitalization (log(Size)), lagged one month return ($RET_{(-1,0)}$), cumulative return over months two to twelve prior to the current month ($RET_{(-12,-2)}$), cash-to-assets ratio as in Palazzo (2012), profitability as in Fama and French (2006), analysts' earnings forecast dispersion as in Diether et al. (2002), idiosyncratic volatility computed as in Ang et al. (2006), volatility risk premium (VRP) as in Goyal and Saretto (2009), the slope of the volatility term structure (VTS slope) as in Vasquez (2017), the bid-ask option spread defined as the difference between bid and ask prices divided by the average of the bid and ask prices, and implied option skew. Newey-West t-statistics are reported in parentheses. The portfolios are weighted by open interest. Significance for high-low returns at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Table IA5: Portfolio Returns Sorted by Realized Volatility and Default Risk Measures

	1-Low Default Risk		3		5-High Default Risk	High-Low
Panel A: Double Sort on Realized Volatility and Credit Rating						
1-Low RV	-0.21	-0.26	-0.28	-0.43	-0.55	-0.34***
	(-2.23)	(-3.21)	(-3.21)	(-5.76)	(-6.17)	(-5.35)
2	-0.19	-0.32	-0.27	-0.42	-0.68	-0.49***
	(-1.58)	(-3.31)	(-2.68)	(-4.58)	(-6.72)	(-5.39)
3	-0.20	-0.21	-0.35	-0.50	-0.84	-0.64***
	(-1.64)	(-1.84)	(-3.17)	(-4.21)	(-6.90)	(-7.66)
4	-0.22	-0.33	-0.54	-0.64	-1.21	-0.99***
	(-1.30)	(-2.62)	(-4.05)	(-4.42)	(-7.46)	(-6.97)
5-High RV	-0.62	-0.75	-0.83	-1.00	-1.73	-1.09**
	(-3.44)	(-3.88)	(-4.28)	(-5.08)	(-3.68)	(-2.35)
High-Low	-0.41***	-0.49***	-0.55***	-0.56***	-1.16**	-0.75
	(-2.71)	(-2.78)	(-3.85)	(-3.57)	(-2.54)	(-1.59)
Panel B: Double Sort on Realized Volatility and Default Probability						
1-Low RV	-0.29	-0.33	-0.37	-0.41	-0.53	-0.24***
	(-3.49)	(-4.20)	(-4.48)	(-4.60)	(-5.78)	(-4.96)
2	-0.29	-0.32	-0.47	-0.56	-0.55	-0.25***
	(-3.04)	(-3.30)	(-4.53)	(-5.39)	(-4.44)	(-2.68)
3	-0.29	-0.38	-0.52	-0.66	-0.65	-0.37***
	(-2.44)	(-3.64)	(-4.72)	(-5.96)	(-4.91)	(-3.50)
4	-0.59	-0.60	-0.74	-0.86	-0.94	-0.36*
	(-3.80)	(-4.14)	(-5.98)	(-5.93)	(-5.17)	(-1.91)
5-High RV	-0.80	-0.98	-1.19	-1.59	-1.77	-0.99***
	(-4.56)	(-5.38)	(-6.22)	(-8.85)	(-8.74)	(-4.77)
High-Low	-0.51***	-0.67***	-0.82***	-1.17***	-1.24***	-0.73***
	(-3.54)	(-4.55)	(-5.31)	(-7.70)	(-7.27)	(-3.56)

This table reports the delta-hedged call option returns (in %) first sorted by realized volatility in the past month, then by credit rating in Panel A (default probability in Panel B) for Optionmetrics stock options from January 1996 to April 2016. Realized volatility is calculated using daily stock returns in the past month. Newey-West t-statistics are reported in parentheses. Significance for high-low returns at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Table IA6: Impact of Credit Rating Announcements on Variance Risk Premiums

	Downgrades		Upgrades	
	$[-6;+6]$	$[-12;+12]$	$[-6;+6]$	$[-12;+12]$
Announcements (#)	1,126	1,228	1,073	1,127
Variance Risk Premium				
VarRP Before Announcement $[-T;-1]$	2.27	2.63	-1.92	-2.03
VarRP After Announcement $[1;+T]$	-0.77	-2.18	-0.66	-0.78
After-minus-before Spread	-3.04***	-4.81***	1.26***	1.25***
	(-3.52)	(-6.33)	(3.89)	(3.21)

This table reports average monthly variance risk premia (in %) around credit rating announcements for Optionmetrics stock options for the period January 1996 to April 2016. We report the average monthly variance risk premium before the announcements $[-T;-1]$ and after the announcements $[1;T]$, for T equal to 6 and 12 months. Variance risk premium is defined as the difference between realized variance for the month and implied variance observed at the end of the previous month. The credit rating announcement occurs in month 0. Credit ratings are provided by Standard & Poor's, which are mapped to 22 numerical values, where 1 corresponds to the highest rating (AAA) and 22 corresponds to the lowest rating (D). Implied volatility (IV) is calculated as the average implied volatility of at-the-money call and put options with 30 days of maturity. We report t-statistics in parentheses. Significance at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Table IA7: Impact of Credit Rating Announcements Using Panel Regressions

Panel A: The Effect of Rating Announcements on Option Returns

	Downgrades		Upgrades	
	Delta-hedged Option Return	Variance Risk Premium	Delta-hedged Option Return	Variance Risk Premium
Dummy	-0.50***	-3.56***	0.04	0.01***
	(-5.20)	(-3.82)	(0.51)	(2.70)
Firm-announcement FE	Y	Y	Y	Y
Month FE	Y	Y	Y	Y
N	10,383	10,208	10,688	10,562
Adj. R^2	0.30%	0.20%	0.20%	0.10%

Panel B: Compare Option Returns Around the Events with Others with Similar Ratings

	(1)	(2)	(3)
Credit Rating	-0.08***	-0.08***	-0.08***
	(-21.13)	(-21.29)	(-21.14)
Down Before	0.14*		0.14*
	(1.81)		(1.89)
Down After	-0.30***		-0.29***
	(-3.46)		(-3.37)
Up Before		0.11**	0.10**
		(2.09)	(2.00)
Up After		0.04	0.04
		(0.64)	(0.58)
Rating FE	Y	Y	Y
Month FE	Y	Y	Y
N	94,469	94,469	94,469
Adj. R^2	0.90%	0.80%	0.90%

This table reports panel regressions to study the impact of credit rating announcements on option returns for Optionmetrics stock options from January 1996 to April 2016. In Panel A, the sample includes stock-month observations six months before and six months after a rating change. We exclude the month before the announcement and the month that the announcement occurs to mitigate the impact of investor overreaction and underreaction around the announcements. The Dummy variable equals to zero for option returns before the announcement [-6,-1] and one for option returns after the announcement [1,6]. Dependent variables are delta-hedged call option return (in %) and variance risk premium (in %). We include firm-announcement fixed effect and month fixed effect in all stock-month observations in the regressions. We report regression results for downgrades (upgrades) in column 2 and 3 (4 and 5). In Panel B, the sample includes all stock-month observations in the regular sample. The dependent variable is delta-hedged call option return (in %). Down Before is dummy variable, which equals to one for stock-month observations that come within six months prior to a downgrade and zero for other observations. Down after is a dummy variable, which equals to one for stock-month observations that come within six months after a downgrade and zero for other observations. Up Before and Up After are similar dummy variables for upgrades. Standard errors are clustered by firm and t-statistics are reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table IA8: Impact of Credit Downgrades When the Implied Volatility Change is Within the Range of [-0.01,0.01]

	[-6,6]	[-12,12]
Announcements (#)	70	70
Delta-hedged Call Option Returns		
Call Return Before Announcement	-0.19	-0.21
Call Return After Announcement	-0.62	-0.74
After-minus-before Spread	-0.43**	-0.53***
	(-2.45)	(-3.01)
Implied Volatility		
IV Before Announcement	0.27	0.32
IV After Announcement	0.27	0.32
After-minus-before Spread	0.00	0.00
	(0.05)	(0.03)
Variance Risk Premium		
VarRP Before Announcement	-0.05	-0.13
VarRP After Announcement	-1.88	-2.56
After-minus-before Spread	-1.83***	-2.43***
	(-2.56)	(-2.78)

This table reports average monthly delta-hedged call and put option returns (in %) around credit rating announcements for Optionmetrics stock options for the period January 1996 to April 2016. The sample include only stock-month observations with six months or twelve months of a rating downgrade, when the change in implied volatility is within the range of [-0.01,0.01]. We report the average monthly option return before the announcements $[-T;-1]$ and after the announcements $[1;T]$, for T equal to 6 and 12 months. The credit rating announcement occurs in month 0. Credit ratings are provided by Standard & Poor's, which are mapped to 22 numerical values, where 1 corresponds to the highest rating (AAA) and 22 corresponds to the lowest rating (D). Implied volatility (IV) is calculated as the average implied volatility of at-the-money call and put options with 30 days of maturity. We report two-sample matched pair t-statistics in parentheses. Significance at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Table IA9: Robustness Tests (Put Options)

Panel A: Delta-hedged Call Returns Sorted by Credit Ratings						
	1	2	3	4	5	High-Low
Period: 1996 to 2008	-0.04	-0.14	-0.08	-0.40	-0.87	-0.82***
	(-0.27)	(-0.81)	(-0.48)	(-2.64)	(-4.78)	(-6.08)
Period: 2009 to 2016	-0.33	-0.34	-0.44	-0.56	-0.74	-0.42***
	(-2.71)	(-2.81)	(-3.64)	(-3.42)	(-3.77)	(-4.16)
Delta-Hedge Put Gain/S	-0.07	-0.15	-0.13	-0.25	-0.51	-0.44***
	(-1.16)	(-2.82)	(-2.17)	(-3.95)	(-6.10)	(-6.32)

Panel B: Delta-hedged Call Returns Sorted by Default Probability						
	1	2	3	4	5	High-Low
Period: 1996 to 2008	-0.15	-0.14	-0.35	-0.41	-0.66	-0.51***
	(-1.12)	(-0.89)	(-2.29)	(-2.50)	(-2.99)	(-3.05)
Period: 2009 to 2016	-0.43	-0.59	-0.73	-0.79	-0.82	-0.39**
	(-3.25)	(-5.32)	(-5.39)	(-4.31)	(-3.38)	(-2.18)
Delta-Hedge Put Gain/S	-0.13	-0.13	-0.27	-0.30	-0.39	-0.26***
	(-2.55)	(-2.26)	(-4.69)	(-4.28)	(-4.66)	(-4.07)

This table reports quintile delta-hedged put option portfolio returns (in %) sorted on two default risk measures for Optionmetrics stock options from January 1996 to April 2016. Default risk measures are credit ratings provided by Standard & Poor's and default probability calculated as in Bharath and Shumway (2008). Panel A (B) reports option portfolios sorted by credit rating (default probability). In each panel, we show the delta-hedged option gain scaled by its initial investment in each quantile in two samples: 1996-2008 and 2009-2016. We also report the delta-hedged option gain scaled by the stock price. Portfolios are weighted with the option's open interest. At the end of each month, we sort options on credit rating or default probability and hold the option portfolios for one month. Newey-West t-statistics are reported in parentheses. Significance for long-short returns at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Table IA10: Delta-hedged Call Returns Sorted by Credit Rating: Subsample Evidence

Weight	Recession	Expansion	Neg. Return	Pos. Return	Liq. Low	Liq. High
EW	-0.79***	-0.71***	-0.89***	-0.72***	-0.82***	-0.62***
	(-10.06)	(-2.88)	(-7.56)	(-7.87)	(-5.39)	(-7.37)
OW	-1.17**	-0.75***	-0.84***	-0.76***	-1.15***	-0.66***
	(-2.49)	(-6.64)	(-5.36)	(-5.73)	(-3.95)	(-4.24)
VW	-0.63**	-0.48***	-0.66***	-0.39***	-0.68***	-0.45***
	(-2.65)	(-6.23)	(-5.59)	(-4.06)	(-3.88)	(-5.99)

This table reports long-short delta-hedged call option portfolio returns (in %) sorted on credit rating for different subsamples for Optionmetrics stock options from January 1996 to April 2016. We report the delta-hedged option gain scaled by its initial investment for different subsamples: recessions and expansions, negative market return and positive market return, high and low liquidity. The crisis period and non-crisis period are classified based on the recession and expansion indicators from The National Bureau of Economic Research (NBER). The negative and positive market return periods are based on months in which S&P 500 return are negative or positive. Periods of high and low liquidity are determined according to the Amihud (2002) liquidity measure of the S&P 500. Portfolios are weighted equally (EW), with the option's open interest (OW), and with the capitalization of the underlying stock (VW). At the end of each month, we sort options on credit rating and hold the option portfolios for one month. Newey-West t-statistics are reported in parentheses. Significance for high-low returns at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Table IA11: Delta-hedged Call Returns and Variance Risk Premia Sorted by Credit Rating: Alphas and Betas

Panel A: Delta-hedged Call Returns	1	2	3	4	5	High-Low
Alpha of Delta-hedged Call	-0.24	-0.31	-0.32	-0.54	-0.89	-0.65***
	(-3.32)	(-3.66)	(-3.61)	(-4.25)	(-7.18)	(-5.74)
Beta of Market Delta-hedged Return	0.25	0.29	0.29	0.28	0.58	0.34***
	(6.11)	(5.26)	(5.80)	(5.20)	(5.07)	(3.57)
Beta of Market Credit Spread	-0.25	-0.23	-0.27	-0.30	-0.25	0.00
	(-5.79)	(-3.21)	(-4.05)	(-4.74)	(-3.34)	(0.08)
Panel B: Variance Risk Premia						
Alpha of Variance Risk Premium	1.44	1.78	0.92	0.59	-0.50	-1.94***
	(1.94)	(1.89)	(1.20)	(0.52)	(-0.41)	(-2.64)
Beta of Market Variance Risk Premium	1.51	2.07	1.65	1.80	3.91	2.40***
	(3.50)	(3.18)	(3.41)	(2.80)	(3.64)	(3.21)
Beta of Market Credit Spread	-1.41	-1.56	-1.68	-2.12	-2.58	-1.17***
	(-2.91)	(-2.03)	(-2.65)	(-2.49)	(-3.25)	(-2.66)

This table reports alphas and betas of time-series regressions of equal-weighted quintile option portfolio returns (variance risk premia) sorted by credit rating in panel A (panel B) for Optionmetrics stock options from January 1996 to April 2016. The factor model includes the delta-hedged option return (variance risk premia) of the S&P 500 and the credit spread in Panel A (Panel B). Credit spread is Moody's seasoned Aaa corporate bond yield relative to yield on 10-Year treasury from St. Louis Fed. The delta-hedged option gain is scaled by its initial investment in each quantile. Newey-West t-statistics are reported in parentheses. Significance for high-low returns at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Table IA12: Default Risk and Equity Option Anomalies (Put Options)

		Default Risk			
	All	Low	Medium	High	High-Low
Size	0.86***	0.49**	0.29	0.78***	0.31
	(5.36)	(2.52)	(1.62)	(2.62)	(0.89)
$RET_{(-1,0)}$	-0.21**	-0.01	-0.17	-0.20	-0.19
	(-2.00)	(-0.10)	(-1.27)	(-1.27)	(-0.94)
$RET_{(-12,-1)}$	0.04	-0.27	0.16	0.19	0.46*
	(0.37)	(-1.64)	(1.20)	(1.04)	(1.89)
Cash-to-Assets Ratio	0.01	0.01	0.02	-0.09	-0.11
	(0.13)	(0.13)	(0.18)	(-0.54)	(-0.51)
Profitability	0.18*	-0.28*	-0.08	0.39**	0.67***
	(1.80)	(-1.90)	(-0.57)	(2.49)	(3.16)
Analyst Dispersion	-0.43***	-0.14	-0.10	-0.48**	-0.35
	(-4.20)	(-1.08)	(-0.63)	(-2.39)	(-1.56)
Idio. Vol.	-0.46***	-0.21	-0.21	-0.41**	-0.17
	(-3.63)	(-1.31)	(-1.59)	(-2.17)	(-0.84)
VRP	0.64***	0.36***	0.64***	0.98***	0.62***
	(4.31)	(2.69)	(4.11)	(4.68)	(2.99)
VTS Slope	0.60***	0.40***	0.66***	0.65***	0.24
	(5.33)	(3.14)	(5.06)	(3.96)	(1.23)
Bid-Ask Spread	-0.29***	0.07	0.09	-0.52***	-0.59**
	(-2.83)	(0.41)	(0.66)	(-2.76)	(-2.04)

This table reports long-short delta-hedged put option returns (in %) for option anomalies for Optionmetrics stock options for the period January 1996 to April 2016. The first column reports the long-short return for each anomaly sorted by quintiles. In the other columns we report the long-short return of each anomaly for low, medium, and high default risk. We perform independent sorts by default risk (3 groups) and by each option market anomaly (5 groups). We report the long-short portfolio that buys quintile 5 and sells quintile 1. The last column reports the difference between high and low default risk portfolios. Default risk is measured with credit ratings provided by Standard & Poor's, which are mapped to 22 numerical values, where 1 corresponds to the highest rating (AAA) and 22 corresponds to the lowest rating (D). The anomalies we report are the firm's market capitalization (Size), lagged one-month return ($RET_{(-1,0)}$), lagged 12-month return ($RET_{(-12,-2)}$), cash-to-assets ratio as in Palazzo (2012), profitability as in Fama and French (2006), analyst earnings forecast dispersion as in Diether et al. (2002), idiosyncratic volatility computed as in Ang et al. (2006), volatility risk premium (VRP) as in Goyal and Saretto (2009), the slope of the volatility term structure (VTS slope) as in Vasquez (2017), and the bid-ask option spread defined as the difference between bid and ask prices divided by the average of the bid and ask prices. Newey-West t-statistics are reported in parentheses. Significance at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Table IA13: Capital Structure Measures and Put Option Returns

Panel A: Leverage and Asset Volatility

	All Firms	Investment Grade	Non-Investment Grade
Intercept	0.003**	0.001	0.004*
	(2.55)	(0.87)	(1.73)
Market Leverage	-0.009***	-0.005***	-0.025***
	(-4.92)	(-3.25)	(-7.49)
Asset Volatility	-0.025***	-0.022***	-0.008**
	(-10.15)	(-8.14)	(-2.09)
Adjusted R^2	0.038	0.038	0.045
Obs.	174,046	102,715	27,081

Panel B: Leverage, Asset Volatility, and Default Risk

	(1)	(2)
Intercept	0.004***	0.003***
	(3.94)	(2.67)
Market Leverage	-0.004***	-0.004***
	(-3.56)	(-3.24)
Asset Volatility	-0.003*	-0.017***
	(-1.67)	(-10.51)
Credit Rating	-0.0005***	
	(-6.80)	
Default Probability		-0.001**
		(-2.47)
Adjusted R^2	0.036	0.036
Obs.	104,838	173,723

This table reports the results from monthly cross-sectional Fama-MacBeth regressions of delta-hedged put option returns leverage and asset volatility for Optionmetrics stock options for the period January 1996 to April 2016. Panel A reports delta-hedged option returns for all firms, for investment and non-investment grade firms. Panel B reports delta-hedged option returns regressed on leverage, asset volatility, and default risk measures. Default risk measures are credit ratings provided by Standard & Poor's and default probability calculated as in Bharath and Shumway (2008). Investment grade companies have a credit rating of BBB- or higher, and non-investment grade companies have a credit rating below BBB-. Leverage is defined as 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 Bharath and Shumway (2008). We report average coefficients and Newey-West t-statistics in parentheses. Significance at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Table IA14: Short-term and Long-term Debt Ratio and Option Returns

	Investment Grade		Non-Investment Grade	
Intercept	0.006	0.008	0.010	0.013
	(3.05)	(4.25)	(3.50)	(4.23)
Market Leverage	-0.005	-0.007	-0.028	-0.028
	(-2.21)	(-3.00)	(-6.62)	(-6.66)
Asset Volatility	-0.033	-0.035	-0.023	-0.023
	(-10.84)	(-11.55)	(-6.05)	(-5.42)
Short-term debt ratio	-0.023		-0.020	
	(-6.18)		(-1.56)	
Long-term debt ratio		-0.010		-0.010
		(-6.35)		(-3.98)
Adjusted R^2	0.044	0.046	0.039	0.044

This table reports the results from monthly cross-sectional Fama-MacBeth regressions of delta-hedged call option returns on leverage, asset volatility, short-term debt ratio and long-term debt ratio for Optionmetrics stock options for the period January 1996 to April 2016. Investment grade companies have a credit rating of BBB- or higher, and non-investment grade companies have a credit rating below BBB-. Leverage is defined as 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 Bharath and Shumway (2008). Short-term (long-term) debt ratio is long term debt due in one (five) year(s) divided by total long term debt. We report average coefficients and Newey-West t-statistics in parentheses. Significance at the 10% level is indicated by *, 5% level by **, and 1% level by ***. Newey-West t-statistics are reported in parentheses. Significance for high-low returns at the 10% level is indicated by *, 5% level by **, and 1% level by ***.