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This Version: Feb. 20, 2012

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ABSTRACT

This study uses a multi-period structural model developed by Chen and Yeh (2006), which extends the Geske-Johnson (1987) compound option model to evaluate the performance of capital structure arbitrage under a multi-period debt structure. Previous studies exploring capital structure arbitrage have typically employed single-period structural models, which have very limited empirical scopes. In this paper, we predict the default situations of a firm using the multi-period Geske-Johnson model that assumes endogenous default barriers. The Geske-Johnson model is the only model that accounts for the entire debt structure and imputes the default barrier to the asset value of the firm. This study also establishes trading strategies and analyzes the arbitrage performance of 369 North American obligators from 2004 to 2008. Comparing the performance of capital structure arbitrage between the Geske-Johnson and CreditGrades models, we find that the extended Geske-Johnson model is more suitable than the CreditGrades model for exploiting the mispricing between equity prices and credit default swap spreads.

I. Introduction

A trader can theoretically purchase equities and short risky bonds or vice versa to profit from relative mispricing of these two instruments. This is known as capital structure arbitrage (or debt-equity trading), and has been the dominant trading activity in hedge funds specializing in credit security markets. Practitioners believe in existing cross-market inefficiencies and try to profit from these opportunities. Researchers are also interested in this issue because the existence of arbitrage profit supports both cross-market inefficiencies and the usefulness of quantitative credit risk models.

Chatiras and Mukherjee (2004) proposed various ways of conducting capital structure arbitrage. For example, arbitraging price discrepancy between the convertible and other forms of company debt is a common form of capital structure arbitrage (see Calamos (2003)). Another form is to use the pricing discrepancy between a company’s high yield debt and call options on its stock.

Many arbitragers, however, replace risky bonds with credit default swap (hereafter CDS) contracts to implement capital structure arbitrage, because CDS contracts possess more detailed data and have more liquidity than risky bonds. In addition, many researchers have shown the significant relationship between CDS spreads and risky bonds spreads.[1] This paper uses a structural model to forecast CDS spreads and conduct different trading strategies based on their forecasted values relative to the realized counterparts. A significant correlation should theoretically exist between CDS spreads and equity prices. Thus, institutional investors such as hedge funds, banks, and insurance companies might apply their trading strategies across credit and equity markets when the valuation models observe mispricing signals

[1] See, for example, Duffie (1999), Lonfstaff et al. (2003) Hull, Predescu, and White (2004), Houweling and Vorst (2005) and Blanco, Brennan, and Marsh (2005).

between a company's CDS spread and equity.

Arbitrage performance, however, can be substantially attributed to model specification. The nature of capital structure arbitrage is to measure and take advantage of the difference between model and market spreads. Valuation of CDS contracts depends on default probability, estimated differently by a variety of underlying models, which plays an important part in arbitrage performance. Most models can predict a theoretical spread that significantly correlates with market spread, but different assumptions regarding the default criteria affect the calculation of CDS spreads and substantially affect arbitrage performance.

When conducting capital structure arbitrage, arbitragers must employ an appropriate structural credit risk model to identify arbitrage opportunities. The structural credit risk models can be traced back to Black and Scholes (1973) and Merton (1974). The Black-Scholes-Merton option formula can exploit the analogy between company equity and a call option that underlies the total asset value of the company with an exercise price equal to the face value of outstanding debt. Chen and Yeh (2006) indicated that if company value falls below the debt level, equity holders do not benefit before all debt holders are paid off and the company defaults on the debt at maturity.

The Merton structural model of valuing equity as a call option is a single-period model. This model is well developed in relating credit risk to capital structure of a firm. However, it is only a single period model, which means that a company can default only at the maturity time of the debt when the debt payment is made. The bankruptcy triggering mechanism is simple because the model ignores the possibility of early default. As a result, the model cannot deal with multiple debt structure, which is considered more realistic.

Two approaches extend the Merton structural model: barrier structural models and compound option models. Barrier structural models assume an exogenous default barrier, and default is defined as the asset value crossing such a barrier. Black and Cox (1976) pioneered the definition of default as the first passage time of firm's value to a default barrier. However, the compound option models developed by Geske (1977), and Geske and Johnson (1984) allow a company to have a series of debts. They employ the compound option pricing technique to characterize default at different times. The main point is that defaults are a series of contingent events; later defaults are contingent upon prior no-defaults. Most importantly, the Geske and Johnson model is the only structural model that endogenously specifies both default and recovery, while the other structural models assume exogenous barrier and recovery.

Literature investigating whether arbitrage opportunities do exist is scant, even though debt-equity trading has become popular. Duarte, Longstaff, and Yu (2005) examined fixed income arbitrage strategies and briefly depicted capital structure arbitrage. Yu (2006) subsequently focused on capital structure arbitrage and was the first to conduct a detailed analysis of trading strategies by implementing the CreditGrades model. Bajlum and Larsen (2008) argued that the opportunities of capital structure arbitrage could vary with model choice and indicated that model misspecification should have a significant effect on the gap between the market and model spreads. Visockis (2011) calculates CDS premiums using two structural models, namely, the Merton model and the CreditGrades model. The results of the Merton model show that average monthly capital structure arbitrage returns are negative. On the other hand, the results of the CreditGrades model show that the capital structure arbitrage strategy produces significant positive average returns in the investigated period.

Hence, instead of using exogenous default barriers as the CreditGrades model does, the current research uses a series of endogenous default barriers to calculate default probabilities across different periods and predicts a theoretical CDS spread more accurately. This paper adopts the extended Geske-Johnson model by Chen and Yeh (2006) and uses the similar trading rule developed by Yu (2006) to evaluate capital structure arbitrage using simulations. Among the related literature, this study is the first to analyze capital structure arbitrage by implementing the multi-period structural model with endogenous default barriers.

The CreditGrades model became popular in the credit derivatives market, was jointly developed by CreditMetrics, JP Morgan, Goldman Sachs, and Deutsche Bank, and subsequently copy written. Sepp (2006) suggested that this approach supplements the Merton model (1974) by providing a link to the equity market, particularly to equity options. The CreditGrades model assumes that firm value follows a pure diffusion with a stochastic default barrier, introduced to make the model consistent with high short-term CDS spreads.

Some investment banks have proposed using the CreditGrades model to measure firm's credit risk. Currie and Morris (2002) and Yu (2006) argued that the CreditGrades model is the preferred framework among professional arbitrageurs by testing the historical data. Yu (2006) used the CreditGrades model to implement a strategy for capital structure arbitrage. The barrier model defines default as the first time asset value to cross the default barrier. However, the barrier over which the default is defined is exogenous and arbitrary. This could cause negative equity value, and an arbitrarily specified barrier could cause incorrect survival probability. Chen and Yeh (2006) have depicted internal inconsistency of an arbitrarily specified barrier.

Yu’s study reveals that the capital structure arbitrageur could suffer substantial losses at an alarming frequency. The current study suspects that this finding could relate to model error because the result is based on the CreditGrades model, which assumes an exogenous barrier and a single period. Hence, its empirical scope is at least limited to both characteristics.

This paper conducts a capital structure arbitrage using the multi-period Geske-Johnson model to implement trading analysis. As indicated in Chen and Yeh (2006), the multi-period Geske-Johnson model is the only model that accounts for the entire debt structure and imputes the default barrier to the asset value of the firm. Chen and Yeh (2006) also provided a binomial lattice for implementing the multi-period Geske-Johnson model instead of conducting expensive high-dimension normal integrals. This work extends the binominal model using numerical optimization techniques to assess firm asset value for matching market equity. This shows that the multi-period Geske-Johnson model can applicably evaluate the credit default swap spread by n-period risky debts and affect the cumulative profits of arbitrage when using simulated trading on 369 obligators during 2004 to 2008. To our knowledge, this is the first paper to apply the multi-period Geske-Johnson model in predicting the CDS spread and evaluating capital structure arbitrage.

The remainder of the paper is outlined as follows. Section 2 briefly presents the extended Geske-Johnson model and the CreditGrades model. Section 3 outlines the trading strategy. Section 4 describes the data. Section 5 conducts an empirical comparison between the extended Geske-Johnson model and the CreditGrades model. Section 6 illustrates some case studies. Section 7 presents the general results of the strategy, and Section 8 concludes all findings.

2. Credit Risk Models

The gap between the market and model CDS spread might vary with model choice because of the substantial difference in model assumptions and methodologies. The arbitrage signal of relative mispricing is delivered by different models that link equity and credit derivative markets. However, the arbitrage signal remains stable if the model can precisely describe CDS spread behavior. This section briefly describes the CreditGrades model and the extended Geske-Johnson model for pricing CDS spread as follows. Further details on the two pricing models can be found in Finger (2002) and Chen and Yeh (2006).

2.1 CreditGrades Model

The CreditGrades model was jointly developed by RiskMetrics, JP Morgan, Goldman Sachs, and the Deutsche Bank. The model derives from the Merton structure model for assessing credit risk, including survival probability and credit spread. The model solves default points with an exogenous default barrier and calculates the CDS spread with uncertain recovery. Currie and Morris (2002) and Yu (2006) noted that the CreditGrades model has been used for many years by participants of various credit derivative markets and has become an industry practice benchmark across numerous traders.

In the CreditGrades model, the firm asset V is assumed as

$$dV_t = \sigma V_t dW_t \tag{1}$$

where σ is the asset volatility and W_t is a standard Brownian motion. The default barrier is given by

$$LD = \bar{L}De^{\lambda Z - \lambda^2/2} \tag{2}$$

where L is the random recovery rate given default, D is the company's debt per share,

$\bar{L}$

is the mean L, λ is the standard deviation of ln (L), and Z is a standard normal random variable. From the perspective of default boundary conditions, the simplest expressions for asset value and asset volatility are given by:

$$V = S + \bar{L}D \tag{3}$$

and

$$\sigma = \sigma_s + \frac{S}{S + \bar{L}D} \tag{4}$$

where S is equity value, and σ_S is equity volatility. The condition that the firm default does not occur is

$$V_0 e^{\sigma Z - \sigma^2 t/2} > \bar{L}De^{\lambda W - \lambda^2/2} \tag{5}$$

where V_0 is initial asset value. The approach solution for survival probability is expressed as

$$q(t) = \Phi\left(-\frac{A_t}{2} + \frac{\ln d}{A_t}\right) - d\,\Phi\left(-\frac{A_t}{2} - \frac{\ln d}{A_t}\right) \tag{6}$$

where $A_t = \sigma^2 t + \lambda^2$

$d = \frac{V_0 e^{\lambda^2}}{\bar{L}D}$.

is the cumulative normal distribution function. This model can calculate a CDS spread by linking the survival probability under constant interest rate, given by

$$c(0,T) = r(1-R)\frac{1 - q(0) + e^{r\xi}(G(T+\xi) - G(\xi))}{q(0) - q(T)e^{-rT} - e^{-rT}(G(T+\xi) - G(\xi))} \tag{7}$$

where $\xi = \lambda^2 / \sigma^2$, and

$$q(T) = d^{z+1/2}\Phi(-\frac{\log(d)}{\sigma\sqrt{T}} - z\sigma\sqrt{T}) + d^{-z+1/2}\Phi(-\frac{\log(d)}{\sigma\sqrt{T}} + z\sigma\sqrt{T})$$

with $z = \sqrt{1/4 + 2r/\sigma^2}$.

The CreditGrades model is easy to implement in practice and to align with the credit derivatives market with historical volatility and debt. However, one disadvantage of the CreditGrades model is its exogenous default barrier, which could cause negative equity value, and incorrect survival probability. This model is based on the single period Merton (1974) framework. Consequently, it cannot deal with multi-period debt structures information, which could be very important in understanding the credit risk of a firm.

2.2 Extended Geske-Johnson Model

The Geske-Johnson model, initially developed by Geske (1977) and then corrected by Geske and Johnson (1984), extends the Black-Scholes-Merton model in the most straightforward manner, in which internal strikes are solved to guarantee positive equity value. The original Geske-Johnson model has some drawbacks, and is thus not widely used. The main problems in this model can be attributed to three reasons: (i) lack of stochastic interest rates, (ii) lack of an efficient implementation algorithm, and (iii) lack of intuition provided by reduced form and barrier structural models.

Chen and Yeh (2006) extended the Geske-Johnson model to n periods and incorporated random interest rates.[2] This is necessary because corporate bonds are

[2] The formulas provided by Geske (1977) are incorrect and corrected by Geske and Johnson (1984). However, Geske and Johnson only presented formulas for $n = 2$. Here, we generalize their formulas to an arbitrary n.

sensitive to both credit and interest rate risks.[3] The current study derives quasi-closed form solutions similar to those in Geske (1977) and Geske and Johnson (1984) by providing a simple algorithm for implementing the model. By recognizing only two state variables (asset price and short interest rate), this article replaces the expensive high-dimension normal integrals by a fast bi-variate lattice. Lastly, a discrete binomial framework shows that the Geske-Johnson model carries the same intuition of reduced form models. Chen and Yeh (2006) extended the Geske-Johnson model to an n period risky debt. The value of T_n-maturity zero coupon debt can be written as:

$$\begin{aligned} D_{GJ}(0,T_n) = \textstyle\sum_{i=1}^{n} P(0,T_i)X_i[\prod_i^-(k_{1n},\cdots,k_{in}) - \prod_i^-(k_{1n-1},\cdots,k_{in-1})] \\ + A(0)[\prod_{n-1}^+(k_{1n-1},\cdots,k_{n-1n-1}) - \prod_n^+(k_{1n},\cdots,k_{nn})] \end{aligned} \tag{8}$$

where

$$\prod_i^{\pm}(k_{1k},k_{2k},\cdots,k_{ik}) = \int_{-\infty}^{\infty}\cdots\int_{-\infty}^{\infty} N_i\left(h_1^{\pm}\left(k_{1k}\right),h_2^{\pm}\left(k_{2k}\right),\cdots,h_i^{\pm}\left(k_{ik}\right)\right)\varphi^{\pm}(r\left(T_1\right),r\left(T_2\right),\cdots,r\left(T_i\right)) \\ dr\left(T_1\right)dr\left(T_2\right),\cdots,dr\left(T_i\right)$$

for $n \geq k \geq i$ where φ is the joint density function of various interest rate levels observed at different times under the forward measure. Note that k_{ij} is a function of r and $h_j^{\pm}\left(k_{ij}\right)$, for $i < j$, is defined as

$$h_i^{\pm}(X_i) = \frac{\ln\dfrac{A(0)}{P(0,T_i)X_i} \pm \dfrac{1}{2}\upsilon^2(0,T_i)}{\upsilon(0,T_i)}$$

$$\upsilon^2(0,T_i) = \int_0^{T_i} \sigma_A{}^2 + \sigma_p{}^2(u,T_i) - 2\rho_{Ar}\sigma_A\sigma_p(u,T_i)du$$

where σ_A is the diffusion term of asset, σ_p is the diffusion term of interest rate, and ρ_{Ar} is the correlation between the asset value and the interest rate. The value of the

[3] High grade bonds contain more interest rate risk than credit risk.

total debt is equal to the sum of all discount debts:

$$\begin{aligned} V_{GJ}(0,T_n) &= \sum_{i=1}^{n} D(0,T_i) \\ &= A(0)[1-\prod_n^+(k_{1n},k_{2n},\cdots,k_{nn})] + \sum_{i=1}^{n} P(0,T_i) X_i \prod_i^-(k_{1n},\cdots,k_{in}) \end{aligned} \tag{9}$$

where $\prod_n^-(k_{1n},k_{2n},\cdots,k_{nn})$ is the total survival probability, $1-\prod_n^-(k_{1n},k_{2n},\cdots,k_{nn})$ is the total (cumulative) default probability, and k_{ij} is the default boundary. Further details of the derivation of Equation (9) can be found in the appendix of Chen and Yeh (2006).

2.3 CDS spread calculation

Using the extended Geske-Johnson model to evaluate a credit default swap is straightforward. For the default protection leg, the valuation of a credit default swap can be written as (in discrete time)

$$\begin{aligned} W(0,T_n) &= \sum_{i=1}^{n} P(0,T_i)[Q(0,T_{i-1}) - Q(0,T_i)] - R_n(0) \\ &= (1-w)\sum_{i=1}^{n} P(0,T_i)[Q(0,T_{i-1}) - Q(0,T_i)] \end{aligned} \tag{10}$$

where $Q\,(0,T_n)$ is the risk neutral survival probability at maturity T_n, $R_n\,(0)$ is the present value of expected recovery, and w is a constant recovery rate. For the premium leg, the present value of the credit default swap can be expressed as

$$W(0,T_n) = s_n \sum_{i=1}^{n} P(0,T_i) Q(0,T_i) \tag{11}$$

where s_n is the CDS spread and the same definition of $c\,(0,\,T)$ in (7). Combining (10) and (11), the CDS spread can be determined by setting the initial value of the CDS contract to zero, as follows:

$$s_n = \frac{\sum_{i=1}^{n} P(0,T_i)[Q(0,T_{i-1}) - Q(0,T_i)] - R_n(0)}{\sum_{i=1}^{n} P(0,T_i) Q(0,T_i)}$$

2.4 Implementation of the extended Geske-Johnson model

Although the extended Geske-Johnson model has a closed form to obtain the survival probabilities for multi-periods (n > 2) of risky debt, the multi-variate normal probability functions cannot be implemented efficiently. Chen and Yeh (2006) developed specific binomial trees with various payoffs to obtain survival probabilities, zero bond values, and equity (compound option) value. This paper extends the binomial trees with different multi-period debt structures to solve the survival probabilities simultaneously by matching the market value of equity. From these probabilities, we can then evaluate a CDS that is written on the company.

$$V_1 = (1-R)\sum \quad P(t_j)(N_{j-1} - N_j)$$

$$V_2 = \sum \quad P(t_j)N_j$$

$$s = V_1 / V_2$$

Following the result, the partial sensitivity of the CDS spread with respect to the asset value is

$$h = \frac{\partial s}{\partial A}$$

The partial sensitivity of the equity with respect to the asset value is

$$h = \frac{\partial E}{\partial A} = N_k$$

Hence, the hedge ratio of CDS with respect to the equity is (first order approximation)

$$h = \frac{\partial s / \partial A}{\partial E / \partial A}$$

The extended Geske-Johnson model is calibrated each period to the CDS spread and stock price and hedge ratio are computed. We then compute weekly performance for some capital structure arbitrage strategies. The main differences between the CreditGrades model and the extended Geske-Johnson model in capital structure arbitrage are the theoretical CDS spreads evaluation and the hedge ratios calculation. Consequently, different models differ in arbitrage strategies and obtain different arbitrage performances.

3 Trading strategy

A credit default swap (CDS) is a bilateral contract between the buyer and seller for protection. Defaults are referred to as credit events covered by CDS contracts. The credit default swap spread is the annual premium amount that the protection buyer must pay annually or quarterly to the protection seller until the contract ends. If the reference obligator (company for credit protection) defaults, the protection seller pays par value of the bond to the protection buyer. CDSs are used to either hedge credit risk or speculate on changes in CDS spreads for profit.

From the CDS pricing model implementation, the arbitrageur sees an opportunity by the trading model based on the mispricing between market CDS spread and theoretical CDS spread. The arbitrageur should either buy CDS and equity or sell both when mispricing occurs due to the changes in capital structure or volatility. An arbitrage opportunity exists for co-movements of CDS spreads and stock prices, and the arbitrageur should obtain a profit from converging spreads or a loss from maintaining co-movements of CDS spreads and stock prices. Arbitrageurs may see an opportunity when the credit market is gripped by fear or when the equity market is slow to react if their views are correct. Hence, many investors develop attractive arbitrage strategies that they keep from other arbitrageurs.

To compare our results with those in Yu (2006), our trading rule follows Yu (2006) in using the same trigger of arbitrage trading when the gap between actual and theoretical CDS spreads increases. By defining the trading trigger α, the current market CDS spread c_t, and the model CDS spread $\hat{c}_t$, we initiate a trade if the following mispricing conditions are satisfied:

$$\hat{c}_t > (1+\alpha)c_t \text{ or } c_t > (1+\alpha)\hat{c}_t \tag{12}$$

When $\hat{c}_t > (1+\alpha)c_t$ is satisfied, indicating that the actual market CDS spread is underpriced, the arbitrageur longs a CDS a notional amount of \$1 and buys $-\delta$ shares of stock as a hedge, where δ is a hedge ratio in the trading rule, and vice versa; a CDS with a notional amount of \$1 and $-\delta$ shares of stock is simultaneously shorted if the $c_t > (1+\alpha)\hat{c}_t$ condition is satisfied. The condition means that the actual market CDS spread is overpriced. For hedging CDS contracts, we define the delta hedge in Equation (13) similarly to Yu (2006):

$$\delta(t,T) = \frac{\partial \pi(t,T)}{\partial E_t}, \tag{13}$$

where $\pi(t,T)$ is the value of the CDS contract, E_t is the equity price at t, and T is the maturity date. The delta hedge ratio can be numerically measured by the rate of change in the CDS contract value relative to the change in equity price. The hedge ratio determines the number of shares of equity needed to buy or sell for a delta neutral portfolio. As indicated by Yu (2006), the empirical results are insensitive to the rebalance of equity position. Therefore, our trading rule adopts a static hedge without rebalancing between the holding periods. We hold the hedging ratio δ fixed throughout the holding period. If the spreads converge during the trading period, we close all the positions.

The purpose of the CDS market is to transfer and hedge credit risk of some obligators. Trading CDS contracts is quite complicated and requires a sufficiently huge amount of capital reserve. To simplify the trading process, we assume that the amount of profit generated has nothing to do with how much capital reserve is employed. In our trading rule, no trades have to be liquidated early because of capital limitation. During the holding period or when mispricing convergence occurs, the value of the equity position is straightforward, and the value of the CDS position is calculated by varying the CDS spread between $c(t, T)$ and $c(0, T)$.

The profit (or loss) realized from closing trade with equity and CDS is equal to

$$profit = \Delta CDS + \Delta P \tag{14}$$

where ΔCDS and ΔP correspond to the change in CDS spreads and stock prices during the holding period or when mispricing convergence occurs. We follow the suggestion of Yu (2006) to adopt 5% transaction cost for trading CDS and 0% transaction cost on equities. We assume a \$1 notional amount in the CDS without initial capital limitation for each trade. Because CDS pricing discrepancies are frequent and persistent, we can compute profit or loss realized by liquidating the CDS position. Therefore, it is relatively easy to discriminate between the CreditGrades and the extended Geske-Johnson model to choose a more suitable CDS pricing model for capital structure arbitrage. Absolute trading return is calculated by each closing trade and the aggregate profit or loss is generated from the total number of trades.

4. Data

This study collected CDS spreads, equity prices, and debt information of public firms in North America. Data on daily CDS spreads were collected from the category of Bond Indices and CDS in the DataStream database. We used only five-year CDS contracts for empirical examination because of liquidity concerns. Firms with a daily CDS spread and available equity data were included in the sample. However, we excluded financial firms and their subsidiaries from the sample ensure a consistent analysis. Debt data were collected from Compustat. Relevant data items included current liability, total debt, and debt due in the first to fifth years. Debt due information in the first to fifth year was not entirely available across every firm in the database. Therefore, we excluded firms with incomplete debt due accounting information in the first to fifth years. Eventually, we used 369 North American industrial companies from 2004 to 2008 in the sample.

A multi-period debt structure plays a unique role in the extended Geske-Johnson model, which assumes that earlier matured debts are more senior than later debts. Chen and Yeh (2006) assumed that default occurs if the firm fails to meet its cash obligations at any given time. The cash obligations are exogenously given and can be regarded as a series of zero coupon bonds issued by the firm. A multi-period debt structure can be viewed as discrete time barriers, and interpreted as cash obligations at any point in time. A firm defaults because of its inability to meet short-term cash obligations rather than meeting total liability.

To construct a complete multi-period debt structure for each firm, this study measured the first cash obligation by current liability, the second to fifth cash obligations by debt due in the second to fifth coming year, and the last cash obligation by total liability subtracted from the sum of the first to fifth cash obligations. We adopted a six-period debt structure for the entire debt due structure. Table 1 presents the definition of a six-period debt structure and its item descriptions and mnemonics appearing in the Compustat database. Equity market value is defined as common shares outstanding at year-end, multiplied by the year-end closing share price. The risk-free rate is defined as five-year U.S. constant maturity Treasury (CMT) yields available in the DataStream database.

[Insert Table 1 Here]

5. Model Comparison

This section employs the two models calibrated to total liability and different debt structures to identify the better model to conduct capital structure arbitrage. In the CreditGrades model, the input parameters include equity price, equity volatility, debt-per-share, recovery rate, standard deviation of the default barrier, and risk-free interest rate. The CreditGrades model is a structural model with an exogenous default barrier; therefore, the default barrier can be total liability instead of debt per share (total liability/common shares outstanding). Finger (2002) suggested estimating the bond-specific recovery rate and the standard deviation of the global recovery rate by numerically optimizing the pricing model with market CDS spreads. Following Finger (2002), we assume the bond-specific recovery rate to equal 0.5 and the standard deviation of the global recovery rate to equal 0.5.

In contrast, calculating CDS spread with a recovery implication in the extended Geske-Johnson model requires n-period debt setting and firm asset value and asset volatility. Firm asset value and asset volatility, however, are difficult to measure using accounting information. This study implements a set of simultaneous equations that can be solved for asset value and asset volatility by matching equity market value and its term structure of equity volatility. We adopt a volatility curve in the model to facilitate the calibration of different CDS spreads. In the original Geske-Johnson model, equity volatility is flat as in the assumption of Black and Scholes (1973). Unfortunately, under this condition, the calibration of the second bond becomes impossible. Hence, we extend the model to include a volatility curve, that is, $v(0,T)^2 = v(0,1)^2 + v(1,2)^2 + \cdots + v(T-1,T)^2$. This flexibility allows us to calibrate the model to additional market CDS spreads. To examine the spread discrepancy between two CDS pricing models, we simply maintain a constant risk-free interest rate in a multi-period setting, although the extended Geske-Johnson model can be implemented with a term structure interest rate. Table 2 presents the parameter definitions required for the two pricing models. The parameters shown in the two models look relatively similar.

[Insert Table 2 Here]

Figures 1 to 3 illustrate the time series of CDS spreads in both models for three obligators. Each figure depicts the CDS spread discrepancy between market spreads and those predicted by different models, the trend for equity price and price volatility, and the trend of total liability and market value. Model spreads appear substantially less volatile in both models. In normal cases, most of the model spreads calculated in the two pricing models are roughly in line with market spreads. However, the model spreads calculated by the extended Geske-Johnson model are considerably closer to market spreads than the CreditGrades model. Table 3 shows the summary statistics of mispricing (realized CDS spreads minus forecasted CDS spreads) across the CreditGrades model and the extended Geske-Johnson model. The extended Geske-Johnson model performs much better than the CreditGrades model in statistical comparisons across different categories of all companies, including investment grade and speculative grade obligators. The statistics show that mispricing in investment grade obligators becomes less dispersed in both models, implying that mispricing arbitrage returns for investment grade obligators should be better than for speculative grade obligators.

[Insert Table 3 Here]

In some special cases, the extended Geske-Johnson model provides a better default prediction than the CreditGrades model. Figure 4 shows that the Avis Budget Group appears very likely to default for Nov 2004 and Aug 2006 according to the prediction made by the extended Geske-John model. However, the CreditGrades model reveals that this company still works well in these two specific periods, even after suffering financial distress during these periods.

The major difference between the extended Geske-Johnson model and the CreditGrades model lies in the consideration of debt structure information. The extended Geske-Johnson model can exploit multi-period debt structure information to predict the default probability of a company. In contrast, the CreditGrades model only incorporates total liability as the basis to predict the default probability of a company. Therefore, the prediction of CDS model spreads by the extended Geske-Johnson model is superior to the CreditGrades model. This study uses the alternative model to account for information in the multi-period debt structure.

[Insert Figure 1-4 Here]

6. Case studies

This section applies the extended Geske-Johnson model to forecast CDS spreads and compare them with realized CDS spreads. We demonstrate normal and extreme cases for arbitrage analysis. Figures 5 and 6 show the time series of CDS spreads, equity price, equity volatility, market value, and debt. The correlations between the spread and the equity value are significantly negative. However, the proposed extended Geske-Johnson model in the trading strategy is capable of predicting market spreads and generating profits from arbitrage trading. Any arbitrage strategy for an individual obligator is very risky. For example, the credit rating of Macy's Inc. belongs to a speculative class. In Figure 5, we find that the market spreads are overestimated and underestimated before and after 2007. The convergence of spreads rarely occurs during the holding period. Therefore, the trading performance of Macy's Inc. is poor.

In contrast, the arbitrage for Weatherford Intl. Ltd. is relatively better. The market spreads are overestimated after 2007, as shown in Fig. 6. The average of market spread and model spread are 40 bps and 80 bps during 2007 to 2008, respectively. After year 2008, the market and model spreads increase to 445 and 847 bps. The model spreads are approximately twice as large as the market spreads. If the CDS spread and the equity price is in a divergence-divergence situation, the portfolio will suffer substantial losses from both the position and the hedge, similar to the arbitrage for Macy's Inc. in Fig. 5. Conversely, the portfolio will make a substantial amount of money in convergence-convergence situations, similar to the case of Weatherford Intl. Ltd. in Fig. 6.

This research also analyzes arbitrage performance generated by simulated trading to produce relevant statistics. In an early discussion, we mentioned that the trigger of arbitrage trading is the minimum threshold to execute an arbitrage automatically. To simplify our analysis, we set up three scenarios for α and holding period: α =0.5, 1.0, and 2.0 and the holding is 30 days, 90 days, and 180 days. Nine possible simulated strategies are implemented by the three different trading triggers, combined with the three holding period assumptions. We assume that capital reserve is unlimited, and no trades have to be liquidated early or for downside protection.

Tables 4 and 5 show the summary statistic of returns calculated based on nine simulated strategies across every individual obligator during 2004 to 2008. Table 4 shows that the mean returns in most cases across different strategies are negative. The largest loss case of 103% of negative return occurred on June 7, 2007, resulting from a tremendous mispricing condition to permit simultaneous selling of CDS and equity. This situation arose because the CDS spread increased from 51.2 bps to 101.1 bps, and the stock price also increased from \$39.15 to \$41.99, which is meant for divergence for both cases in conducting arbitrage strategies (α=0.5, HP=30) over a 30-day holding period.

In contrast, from Table 5, the mean returns in most cases are positive, and the largest profit case with 171% of positive return occurred on December 2, 2008, resulting from a tremendous mispricing condition to permit simultaneous buying of CDS and equity. The reason behind this scenario is that spread increased from 320 bps to 445 bps, and the stock price increased from \$10.15 to \$10.82. The enlarged credit spreads and increased stock prices over a 30-day holding period resulted in a significantly positive return.

[Insert Table 4 Here]

[Insert Table 5 Here]

7. Results

This section establishes a trading strategy to evaluate capital structure arbitrage across all obligators from 2004 to 2008. Table 6 shows the summary statistics for all obligators. The variables presented include credit rating from Standard & Poor's, CDS spread, leverage, volatility, and the correlation between CDS spread and equity value. Table 6 shows that the correlations range from 2% to -14%. The average of all correlations across obligators is -0.08.[4] However, as shown in Table 6, a lower spread is associated with a lower volatility and leverage, consistent with theoretical spread predictions from CDS pricing models.

Table 7 shows the summary statistics of monthly returns based on nine simulated strategies for all obligators. The results show that the strategies have a few opportunities to produce positive mean returns for trading all obligators. The monthly mean returns resulting from a trading trigger α =0.5 are negative across all holding periods. A longer holding period mean return gradually migrates to be negative and the mean return for a larger trading trigger gradually turns to positive. Table 7 shows that a lower α typically implies significant negative returns of arbitrage Minimum mean returns are also relatively low across all strategies because of no downside protection for liquidation.

In Table 8, as trading strategies are implemented separately on investment-grade and speculative-grade obligators, in most cases, the former produces positive mean returns and the latter generates mostly negative mean returns. For investment-grade obligators, a longer holding period leads to a lower mean return and most cases produce a negative return within a 180-day holding period. The strategy of a short holding period with a high trading trigger (HP=30, α=2) yields monthly mean returns of 1.87% for investment-grade obligators and -2.47% for speculative-grade obligators. As shown in Table 6, speculative-grade obligators are less significant than

[4] This is consistent with Yu (2006) and Currie and Morris (2002). Yu (2006) found that individual correlations ranged from -5% to -15% according to different data sample periods, indicating that capital structure arbitrage may be ineffective because of a weak correlation between the two markets.

investment-grade obligators in the correlation between equity and credit derivatives markets. Therefore, low mean returns of arbitrage are predictable in the case of speculative-grade obligators, where the effect is similar to the case of investment-grade, despite the negative mean returns.

Arbitrage returns resulting from the extended Geske-Johnson model with different trading strategies is similar to the results in Yu (2006). Capital structure arbitrage between equity and credit derivatives markets is highly complex. Trading with a larger trading trigger and a shorter holding period based on investment-grade obligators is a seemingly profitable arbitrage. On the contrary, arbitrage with long holding periods may suffer huge loss because the correlation between the equity market and the credit derivatives market is insignificant and results in tremendous mispricing.

[Insert Table 6 Here]

[Insert Table 7 Here]

[Insert Table 8 Here]

8. Conclusion

This paper uses the extended Geske-Johnson model combined with different trading strategies to evaluate capital structure arbitrage. The comparison between the extended Geske-Johnson model and the CreditGrades model shows that both models are similar in CDS spread calculation and are consistent with the market CDS spread. However, the extended Geske-Johnson model with a multi-period debt structure can predict default much earlier than the CreditGrades model in extreme cases, because the extended Geske-Johnson model can exploit multi-period debt structure information to predict the default probability of a company. In contrast, the

CreditGrades model only considers total liability as the reference to predict the default probability of a company. Both models have different methodologies to deal with corporate debt structures, and therefore different prediction power regarding the default risk of a firm.

Debt structure is a key factor in driving a firm to default. This study is the first to incorporate multi-period debt structures using the extended Geske-Johnson model to predict CDS spread and evaluate capital structure arbitrage. Although the statistics regarding arbitrage show an insignificant profit generated, there might still be room for improvement if enhanced calibration methods can used to predict CDS spread or default probability. The availability of more precise multi-period debt structure information would allow the extended Geske-Johnson model to conduct arbitrage strategies that are more appropriate, to become a more suitable tool to implement capital structure arbitrage than the CreditGrades model.

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Table 1： Definition of debt structure

This table presents the definition of six-period debt structure relative to the item description and mnemonic of Compustat. All related debts are annual data, and the six-period debt structure can be viewed as cash obligation at different year.

Item Description	Mnemonic	Item Number	Extended Geske model Debt structure
Debt in Current Liabilities - Total	DLC	A34	1st period
Debt Due in 2nd Year	DD2	A91	2nd period
Debt Due in 3rd Year	DD3	A92	3rd period
Debt Due in 4th Year	DD4	A93	4th period
Debt Due in 5th Year	DD5	A94	5th period
Total Liabilities	LT	A181	
Total Liabilities subtract the sum of DLC,DD2, DD3,DD4 and DD5			6th period

Table 2: Input parameters of two pricing models

This table presents input parameters of two pricing models. The CreditGrades model uses total liability and zero drift of asset value to derive the CDS spread from historical equity volatility. The extended Gesek-Johnson model capture spread employs debt structure as cash obligations by a call option to matching market firm's equity in the multi-period behavior.

Model / Input Parameters	CreditGrades (default barrier)	Extended Geske-Johnson (multi-period analysis)
Debt	Total liability	Debt structure
Equity	Equity price	Equity price
Equity Volatility	rolling 1000-day historical volatility	rolling 1000-day historical volatility
Asset	S+LD defined as model	Matching equity by model
Risk-free rate	5-year U.S. Treasury yields	5-year U.S. Treasury yields
Recovery rate	0.5	0.5
Standard deviation of the default barrier	0.3	none

Table 3: Summary statistics of the mispricing

This table reports summary statistics of the mispricing for all obligators based on CreditGrades and extended Geske-Johnson models, respectively. The mispricing is defined as (actual spreads - model spreads) The statistics are presented across the classification of grades, including investment and speculative obligators.

		Mean	Median	Std	Max	Min
CreditGrades model	All	-185	-79	539	3520	-7068
	Investment	-96	-53	145	178	-1961
	Speculative	-361	-215	864	3520	-7068
Extended Geske-Johnson model	All	-60	11	324	1276	-2161
	Investment	-11	15	130	170	-1395
	Speculative	-217	-51	602	1276	-2161

Note: mispricing = market CDS spread － model CDS spread. Std is standard deviation. Unit: basis points

Table 4: Holding period return for Macy's Inc.

This table presents holding period return for Macy's Inc based on nine simulated strategies during the period 2004-2008. Each trade does not have to be liquidated early and to limited capital reserve.

					Monthly Return		
HP	α	N	N_1	N_2	Mean	Minimum	Maximum
30	0.5	48	22	26	-9.36%	-103.00%	26.38%
	1	38	17	21	-6.22%	-91.90%	25.89%
	2	17	7	10	-5.43%	-39.43%	13.44%
90	0.5	48	24	24	-2.96%	-40.35%	30.44%
	1	38	22	16	-0.10%	-40.35%	30.44%
	2	17	10	7	0.44%	-5.74%	7.17%
180	0.5	48	22	26	-3.70%	-56.38%	9.81%
	1	38	21	17	0.26%	-11.35%	9.81%
	2	17	8	9	0.66%	-3.15%	5.34%

Note: HP=holding period (days); α=trading trigger; N is the total number of trades; N_1 is trades with positive holding period returns; N_2 is trades with negative holding period returns.

Table 5: Holding period return for Weatherford Intl. Ltd.

This table presents holding period return for Weatherford Intl Ltd based on nine simulated strategies during the period 2004-2008. Each trade does not have to be liquidated early and to limited capital reserve.

HP	α	N	N_1	N_2	Monthly Return Mean	Monthly Return Minimum	Monthly Return Maximum
30	0.5	44	40	4	12.25%	-21.79%	171.27%
	1	25	22	3	14.30%	-14.22%	171.27%
	2	7	6	1	5.75%	-12.34%	18.59%
90	0.5	44	35	9	4.85%	-14.20%	31.18%
	1	25	20	5	5.41%	-6.80%	31.18%
	2	7	3	4	-0.32%	-6.80%	9.09%
180	0.5	44	31	13	0.73%	-48.80%	9.53%
	1	25	17	8	0.55%	-48.80%	9.23%
	2	7	1	6	-2.34%	-5.61%	7.51%

Note: HP=holding period (days); α=trading trigger; N is the total number of trades; N_1 is trades with positive holding period returns; N_2 is trades with negative holding period returns.

Table 6: Summary statistics for the 369 obligators from 2004 to 2008

This table reports summary statistics for all obligators. The variables presented are averages over the period 2004-2008, including credit rating from Standard & Poor's, CDS spread, leverage, volatility, and correlation between changes in the spread and the equity value.

Rating Grade	Rating	N	Spread(bps)	Volatility	Leverage	Corr.
Investment	AAA	5	13.77	0.47	0.05	-0.07
	AA	10	22.52	0.55	0.09	-0.09
	A	74	39.75	0.59	0.16	-0.11
	BBB	144	84.73	0.68	0.27	-0.13
Speculative	BB	52	209.89	0.63	0.35	-0.14
	B	43	489.89	0.58	0.52	-0.08
	CCC	8	534.40	0.70	0.49	-0.09
	CC	1	403.10	0.80	0.32	0.02
	D	7	908.66	0.48	0.66	-0.04
	Not rated	25	250.18	0.84	0.55	-0.09

Note: N is the number of obligators; Spread is the average of CDS spreads；Volatility is the historical volatility; Leverage is the average of leverage defined as total liability divided by sum of total liability and market value；Corr is the average of correlation between changes of the equity and CDS spread; Not rated represents no rating.

Table 7: Summary of monthly return for statistic arbitrage

This table shows the summary statistic of monthly returns based on nine simulated strategies for all obligators during 2004 to 2008. Studying nine simulated strategies were implemented by the trading trigger of 0.5, 1.0 and 2.0 combination with the holding period of 30 days, 90 days, and 180 days. The trigger is the minimum threshold to execute an arbitrage trade.

						Monthly Return		
obligators	HP	α	N	N_1	N_2	Mean	Minimum	Maximum
	30	0.5	12442	8457	3985	-0.42%	-372.47%	401.49%
		1	10669	7349	3320	-0.04%	-372.47%	401.49%
		2	8457	5988	2469	0.87%	-372.47%	401.49%
	90	0.5	12442	7868	4574	-0.38%	-268.19%	198.16%
		1	10669	6823	3846	-0.21%	-268.19%	198.16%
		2	8457	5522	2935	0.13%	-268.19%	198.16%
	180	0.5	12440	7352	5088	-0.46%	-171.22%	138.35%
		1	10667	6344	4323	-0.38%	-171.22%	138.35%
		2	8456	5069	3387	-0.23%	-171.22%	138.35%

Note: HP=holding period (days); α=trading trigger; N is the total number of trades; N_1 is trades with positive holding period returns; N_2 is trades with negative holding period returns.

Table 8: Summary of monthly return for investment and speculative grades

This table shows summary of monthly return for investment and speculative grade obligators during 2004 to 2008. Studying nine simulated strategies were implemented by the trading trigger of 0.5, 1.0 and 2.0 combination with the holding period of 30 days, 90 days, and 180 days. The trigger is the minimum threshold to execute an arbitrage trade.

						Monthly Return		
Rating Grade	HP	α	N	N_1	N_2	Mean	Minimum	Maximum
Investment	30	0.5	9222	6711	2511	1.42%	-372.47%	321.13%
(AAA~BBB)		1	8074	5913	2161	1.64%	-372.47%	321.13%
		2	6559	4890	1669	1.87%	-372.47%	321.13%
	90	0.5	9222	6154	3068	0.03%	-268.19%	155.15%
		1	8074	5408	2666	0.12%	-268.19%	155.15%
		2	6559	4432	2127	0.08%	-268.19%	103.61%
	180	0.5	9221	5620	3601	-0.29%	-171.22%	107.90%
		1	8073	4904	3169	-0.27%	-171.22%	107.90%
		2	6559	3966	2593	-0.37%	-171.22%	67.83%
Speculative	30	0.5	3260	1780	1480	-5.60%	-355.61%	401.49%
(below BB)		1	2631	1466	1165	-5.18%	-355.61%	401.49%
		2	1927	1121	806	-2.47%	-320.01%	401.49%
	90	0.5	3260	1743	1517	-1.56%	-184.99%	198.16%
		1	2631	1440	1191	-1.33%	-146.30%	198.16%
		2	1927	1108	819	0.20%	-123.36%	198.16%
	180	0.5	3259	1756	1503	-0.96%	-111.62%	138.35%
		1	2630	1460	1170	-0.79%	-108.46%	138.35%
		2	1926	1116	810	0.19%	-104.86%	138.35%

Note: HP=holding period (days); α=trading trigger; N is the total number of trades; N_1 is trades with positive holding period returns; N_2 is trades with negative holding period returns.

Figure 1: The time-series of CDS spreads for Alcona Inc.

This figure depicts the spreads variation among market and models, the variation of equity price and price volatility, and the variation of total liability and market equity. The top figure represents the CDS spreads for different models and market data. The middle figure represents the equity price and the price volatility, respectively. The bottom figure shows the total liability and market value.

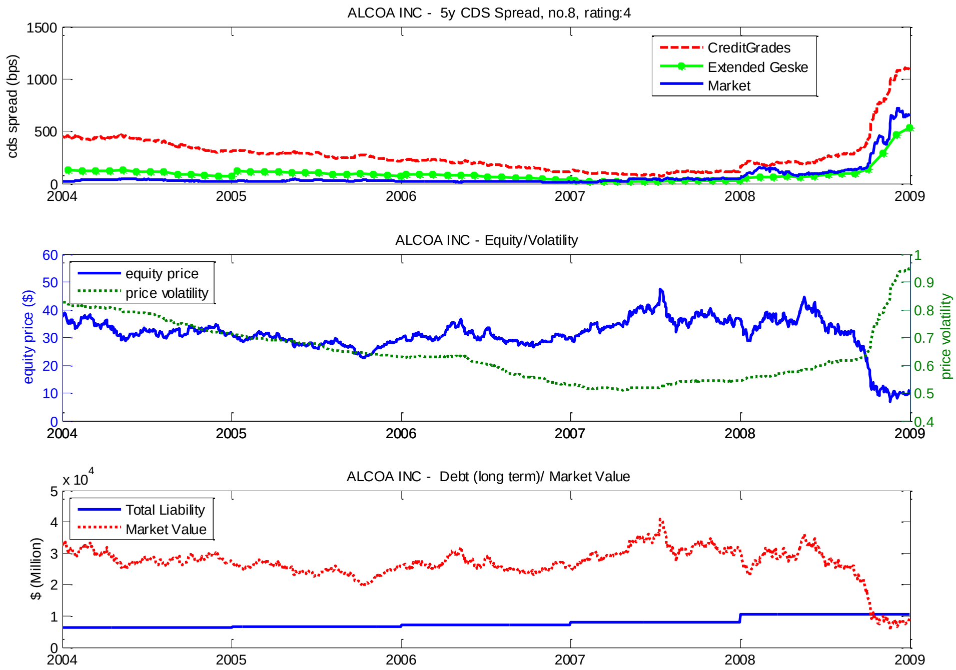

Figure 2: The time-series of CDS spreads for Tenet Healthcare Corp.

This figure depicts the spreads variation among market and models, the variation of equity price and price volatility, and the variation of total liability and market equity. The top figure represents the CDS spreads for different models and market data. The middle figure represents the equity price and the price volatility, respectively. The bottom figure shows the total liability and market value.

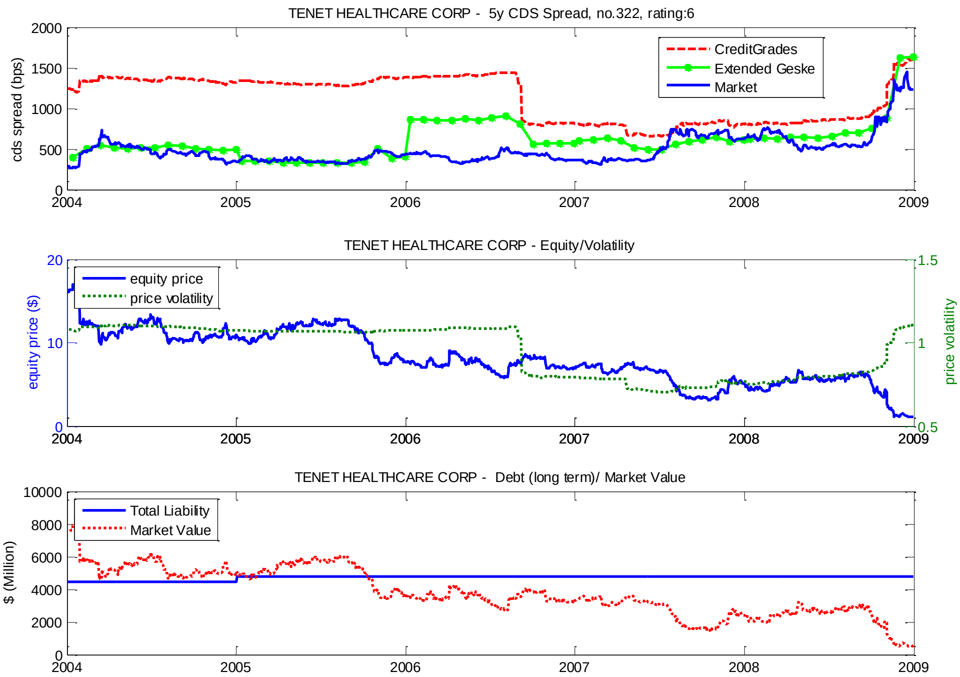

Figure 3: The time-series of CDS spreads for Macy's Inc.

This figure depicts the spreads variation among market and models, the variation of equity price and price volatility, and the variation of total liability and market equity. The top figure represents the CDS spreads for different models and market data. The middle figure represents the equity price and the price volatility, respectively. The bottom figure shows the total liability and market value.

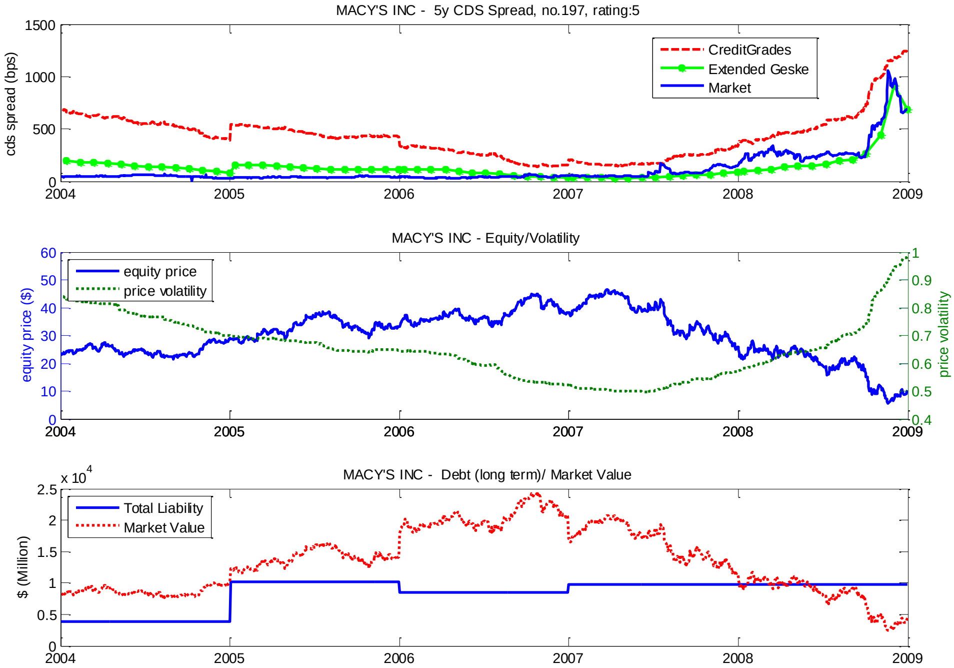

Figure 4: The time-series of CDS spreads for Avis Budget Group Inc.

This figure depicts the spreads variation among market and models, the variation of equity price and price volatility, and the variation of total liability and market equity. The top figure represents the CDS spreads for different models and market data. The middle figure represents the equity price and the price volatility, respectively. The bottom figure shows the total liability and market value.

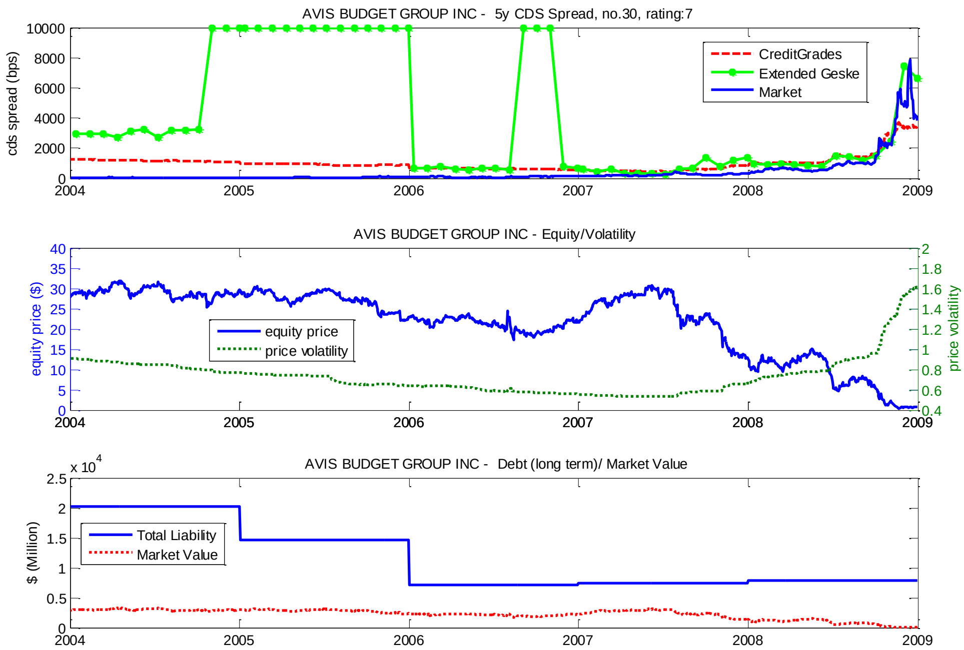

Figure 5: Arbitrage analysis for Macy's Inc.

This figure illustrates the time series of CDS spreads, equity price, equity volatility, market value, and debt. The correlations between the spread and the equity value are negative obviously. This figure shows mostly the negative mean return in different strategies for Macy's Inc. from Table 4, although the model CDS spreads line on the both sides of the market CDS spread. The top figure represents the CDS spreads for the Extended-Geske model and market data. The middle figure represents the equity price and the price volatility, respectively. The bottom figure shows the total liability and market value.

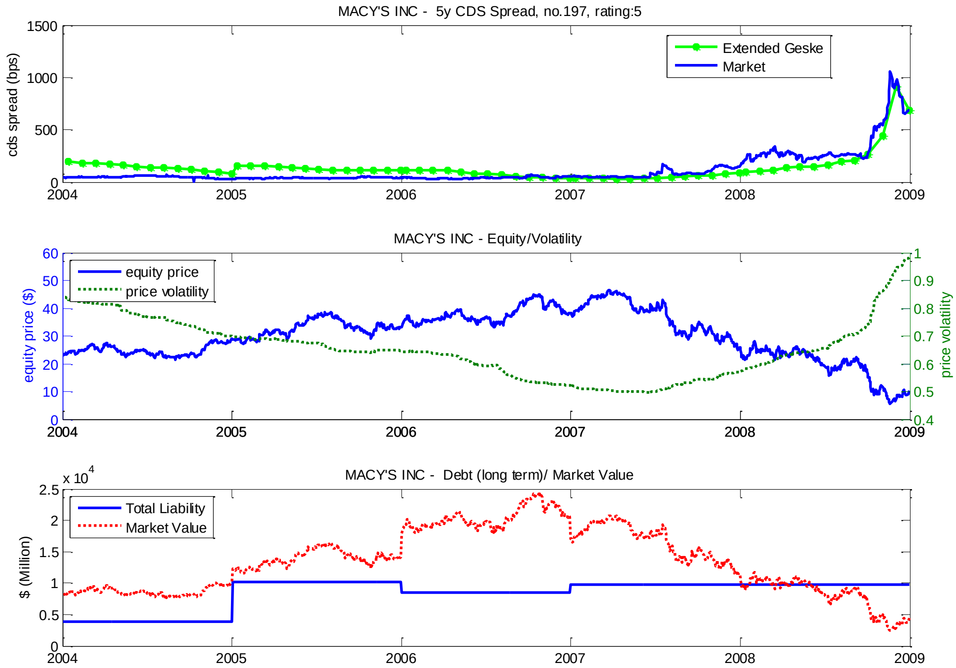

Figure 6: Arbitrage analysis for Weatherford Intl. Ltd.

This figure illustrates the time series of CDS spreads, equity price, equity volatility, market value, and debt. The correlations between the spread and the equity value are negative obviously. This figure shows the arbitrage for Weatherford Intl. Ltd. has succeeded from Table 5. The top figure represents the CDS spreads for the Extended-Geske model and market data. The middle figure represents the equity price and the price volatility, respectively. The bottom figure shows the total liability and market value.